Bacteria TMDLs for Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watersheds, Virginia

Submitted by

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Executive Summary

This report presents the development of Bacteria TMDLs for the Cub Creek, Turnip Creek, an unnamed tributary (UT) of Buffalo Creek, and Staunton River watersheds, located in the Lower Roanoke River Basin. Segments of Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform bacteria. These segments were also included on Virginia's 2002 303(d) Report on Impaired Waters and 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The impaired segments are located in the Lower Roanoke River Basin in the south central Virginia.

Description of the Study Area

The impaired segment of the Staunton River begins in Campbell County and flows through the borders of Campbell and Pittsylvania Counties into the borders of Halifax and Charlotte Counties. Cub Creek, Turnip Creek, and Buffalo Creek (UT) are tributaries to the Staunton River and are located in Charlotte County. All four streams are located in the Lower Roanoke River Basin (USGS Cataloging Unit 03010101 and 03010102). The watershed that encompasses the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River bacteria impairments is approximately 1,477,287 acres or 2,308 square miles. The watershed drains portions of Bedford, Franklin, Henry, Campbell, Pittsylvania, Appomattox, Charlotte, and Halifax counties.

Approximately 24 percent of the drainage basin is located in the Bedford County. A small portion of the watershed is located in Appomattox and Henry Counties (4.5 and 0.5 percents respectively). The remainder of the watershed is divided among Campbell, Charlotte, Franklin, Pittsylvania, and Halifax Counties (19, 18, 12, 11, and 11 percent, respectively). The watershed makes up 100 percent of the land area in the Bedford City, 89 percent of Charlotte County, 86 percent of Campbell County, 72 percent of Bedford County, 37 percent of Franklin County, 30 percent each of Halifax and Appomattox Counties, 27 percent of Pittsylvania County, and three percent of Henry County.

Interstates 81 and 581 are located to the west of the watershed. US highways 29, 220, and 501 run generally from North to South through the watershed. US highways 460 and 221 run through the North-West section of the watershed.

Bacteria TMDLs have already been approved for six impaired streams in the watershed: Machine Creek, Elk Creek, Sheep Creek, Little Otter River, Big Otter River and Falling River. The first five impairments all flow into Big Otter River, which then flows into the Staunton River, just upstream of the Campbell County/Pittsylvania County line. The last impairment flows through Falling River into the Staunton River at the border of Campbell, Charlotte, and Halifax Counties. The TMDL developed for this study will include the results of the bacteria TMDLs developed for the Big Otter River and the Falling River watersheds.

Impairment Description

Segments of Cub Creek, Turnip Creek and the Staunton River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform bacteria. These segments as well as a segment of Buffalo Creek (UT) were also included on Virginia's 2002 303(d) Report on Impaired Waters and 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The impaired segments are located in the Lower Roanoke River Basin in southwestern Virginia. The watershed is located in the hydrologic units (HUC) 03010101 and 03010102. The impaired watersheds include portions of Campbell, Charlotte, Halifax, Pittsylvania, and Appomattox counties.

The impaired segment of Cub Creek (VAC-L37R-01) extends for 14.21 miles from Big Cub Creek to Terry Creek. Eight out of 21 samples (38%) taken at ACUB010.96 between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100mL.

The impaired segment of Turnip Creek (VAC-L36R-01) extends for 2.7 miles from Buck Branch downstream to its mouth at the Staunton River. Eight (8) out of 28 samples

(29%) collected at ATIP002.55 between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100mL.

The entire length of a Buffalo Creek (UT) (Segment VAC-L40R-05) is impaired from its headwaters to Buffalo Creek. Five out of 10 samples (50%) collected at A4XMC000.54 between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100mL.

In addition to the impaired segments on Cub Creek, Turnip Creek, Buffalo Creek (UT), this report also addresses an 80.46-mile segment of the Staunton River (VAC-L19R-01) including the Staunton River mainstem from Leesville Dam downstream to a pipeline crossing approximately 5.4 miles downstream of the Route 360 Bridge. The total length of these five impaired segments is 100.25 miles.

Applicable Water Quality Standards

At the time of the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River listings, the Virginia Bacteria Water Quality Standard was expressed in fecal coliform bacteria; however, the bacteria water quality standard has been recently changed and is now expressed in E. coli. Virginia's bacteria water quality standard currently states that E. coli bacteria shall not exceed a geometric mean of 126 E. coli counts per 100 ml of water for two or more samples over a 30-day period or an E. coli concentration of 235 counts per 100 ml of water at anytime. However, the loading rates for watershed-based modeling are available only in terms of the previous standard, fecal coliform bacteria. Therefore, the TMDL was expressed in E. coli by converting modeled daily fecal coliform concentrations to daily E. coli concentrations using an in-stream translator. This TMDL was required to meet both the geometric mean and instantaneous E. coli water quality standard.

Watershed Characterization

Land use characterization was based on National Land Cover Data (NLCD) developed by USGS. Land use was calculated for the study area and does not include the Big Otter, Falling River, or Smith Mountain Lake drainage areas. Dominant land uses in the watershed are forested land (70%) and agricultural land (24%), which account for a combined 94% of the total land area in the watershed. The potential sources of fecal coliform include run-off from livestock grazing, manure applications, industrial processes, residential, and domestic pets waste. Some of these sources are driven by dry weather and others are driven by wet weather. The potential sources of fecal coliform in the watershed were identified and characterized. These sources include permitted point sources, failed septic systems and straight pipes, livestock, wildlife, and pets.

An inventory of the livestock residing in the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton watershed was conducted using county-specific data obtained from the United State Department of Agriculture (USDA) National Agricultural Statistics Service. The data and information indicate the following:

- beef and dairy cattle exist on the pasture areas of the watershed
- no poultry operations exist in the watershed
- no swine operations exist in the watershed
- no feedlots are located in the watershed
- alternative water has been implemented in the watershed to minimize livestock activity in the streams

Data obtained from the DEQ's South Central Regional Office indicate that there are 45 individually permitted facilities located in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed, not including the Falling River and Big Otter Watersheds. For TMDL development, mean flow values were considered representative of flow conditions at each permitted facility, and were used in the model set-up and calibration. For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

TMDL Technical Approach

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used as a tool to predict the in-stream water quality conditions of delineated watershed under varying scenarios of rainfall and fecal coliform loading. The results from the developed model were used to develop the TMDL allocations based on the existing fecal coliform load. HSPF is a hydrologic, watershed-based water quality model. Basically, this means that HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineating the watershed into smaller subwatersheds
- entering the physical data that describe each subwatershed and stream segment
- entering values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

The TMDLs developed in this study include the results of the bacteria TMDLs developed for the Big Otter River and the Falling River watersheds. In addition, flow and water quality data from the American Electric Power (AEP) Leesville Power Plant (outlet of the Smith Mountain Lake Watershed) is also used for the development of these TMDLS. In other words, hydrology and water quality information from the Falling River Watershed, the Big Otter Watershed, and the Smith Mountain Lake Watershed are used as boundary conditions to the HSPF model simulating hydrology and water quality in the study area.

For this TMDL, the watersheds were delineated into 82 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data. Stream flow data were available from severable stations and utilized in the hydrology calibrations and TMDLs development.

Weather data for the Roanoke International Airport, the Lynchburg WSO Airport, and the John H. Kerr Dam were obtained from NCDC. The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). For this TMDL, the recorded data at the three stations were combined based on their proximity to each model segment in the watershed.

HSPEXP software was used to calibrate the hydrology of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. After each iteration of the model, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. Using the recommended default criteria as target values for an acceptable hydrologic calibration, the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River model was calibrated for January 2000 to December 2001 at the flow stations 02059500 (Goose Creek near Huddleston, VA) and 02066000 Staunton River at Randolph, VA. The period of January 2001 to December 2004 was used to validate the HSPF model. The hydrologic calibration parameters were adjusted until there was a good agreement between the observed and simulated stream flow, thereby indicating that the model parameterization is representative of the hydrologic characteristics of the study areas. The model results closely matched the observed flows during low flow conditions, base flow recession and storm peaks.

Instream water quality data for this station was retrieved from STORET and DEQ, and was evaluated for potential use in the set-up, calibration, and validation of the water quality model. The time period spanning from January 1997 to December 1999 was used for the water quality calibration and the time period spanning from January 2000 to December 2004 was used for water quality calibration of the model. The VADEQ water quality stations used in the water quality simulations are presented in **Table E-1**.

Table E-1: Water Quality Station used in the HSPF Fecal Coliform Simulations

Watershed	Water Quality Station	HSPF Model segment
Staunton	4AROA129.55	49
Staunton	4AROA097.46	41
Staunton	4AROA05912	6
Turnip Creek	4ATIP002.55	36
Cub Creek	4ACUB010.96	30
Buffalo Creek (UT)	4XMC000.54	4

The existing fecal coliform loading was calculated based on current watershed conditions. Virginia has recently changed its bacteria standard from fecal coliform to E. coli; therefore, modeled fecal coliform concentrations were changed to E. coli concentrations using a translator. Water quality standards for both fecal coliform and E. coli were exceeded for the most part during this time period.

TMDL Calculations

The TMDL represents the maximum amount of a pollutant that the stream can receive without exceeding the water quality standard. The load allocation for the selected scenarios was calculated using the following equation:

$$TMDL = \sum WLA + \sum LA + MOS$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. The MOS was implicitly incorporated in this TMDL. Implicitly incorporating the MOS required that allocation scenarios be designed to meet a 30-day geometric mean E. coli standard of 126 cfu/100 ml and the instantaneous E. coli standard of 235 cfu/100 ml with 0% exceedance.

Typically, there are several potential allocation strategies that would achieve the TMDL endpoint and water quality standards. A number of load allocation scenarios were developed to determine the final TMDL load allocation scenario.

For the hydrologic period from January 1995 to December 2004, fecal coliform loading and instream fecal coliform concentrations were estimated for the various scenarios using the developed HSPF model of the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River watersheds. Because Virginia has recently changed its bacteria standard from fecal coliform to E. coli, modeled fecal coliform concentrations were translated to E. coli concentrations, and the TMDL allocation plan was developed to meet geometric mean and instantaneous E. coli standards. Based on the load-allocation scenario analyses, the TMDL allocation plans that will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous E. coli water quality standard of 235 cfu/100 ml are presented in **Table E-2**:

Table E-2: Allocation Plan Loads for E. coli (% reduction) for Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River

Watershed	Human Sources (Failed septic systems and straight pipes)	Livestock (Direct Instream Loading)	Agricultural and urban non-point sources	Wildlife
Cub Creek	100%	100%	95%	70%
Turnip Creek	100%	100%	90%	70%
Buffalo Creek	100%	100%	94%	70%
Staunton River	100%	100%	82%	70%

The summaries of the bacteria TMDL allocation plan loads for Cub Creek, Turnip Creek, Buffalo Creek, and Staunton are presented in **Table E-3**.

Table E-3: Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDL Allocation Plan Loads for E. coli (cfu/year)

Watershed	Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
Cub Creek	2.87E+10	1.50E+12	Implicit	1.53E+12
Turnip Creek	2.61E+09	6.61E+11	Implicit	6.63E+11
Buffalo Creek*	≤1.65E+8	1.64E+10	Implicit	1.65E+10
Staunton River	2.34E+13	5.43E+13	Implicit	7.77E+13

* Waste load allocations for watersheds without permitted point sources are denoted as ≤1% based on Virginia DEQ guidance.

TMDL Implementation

The Commonwealth intends for this TMDL to be implemented through best management practices (BMPs) in the watershed. Implementation will occur in stages. The benefits of staged implementation are: 1) as stream monitoring continues to occur, it allows for water quality improvements to be recorded as they are being achieved; 2) it provides a measure of quality control, given the uncertainties that exist in any model; 3) it provides a mechanism for developing public support; 4) it helps to ensure the most cost effective practices are implemented initially, and 5) it allows for the evaluation of the TMDL's adequacy in achieving the water quality standard.

Three allocation scenarios are presented in **Tables E-4, E-5, E-6,** and **E-7** for the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River respectively. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

Table E-4: Cub Creek Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100%	100%	85%	95%	63%	0%	10%
2	100%	50%	50%	50%	0%	12%	100%
3	100%	75%	75%	75%	0%	7%	77%

Table E-5: Turnip Creek Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100%	100%	85%	95%	63%	0%	10%
2	100%	50%	50%	50%	0%	12%	100%
3	100%	75%	75%	75%	0%	7%	77%

Table E-6: Buffalo Creek (UT) Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100%	100%	96%	70%	55%	0%	10%
2	100%	50%	50%	50%	0%	10%	100%
3	100%	75%	75%	75%	0%	6%	93%

Table E-7: Staunton River Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100	100	52	90	70	1%	10%
2	100	50	50	50	0	9%	47%
3	100	75	75	75	0	4%	3%

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

Public Participation

The development of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDLs would not have been possible without public participation. Two Technical Advisory Committee (TAC) meetings and two public meetings were held in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. The following is a summary of the meeting objectives and attendance.

TAC Meeting No. 1. The first TAC meeting was held in the Town of Brookneal on September 15, 2004 to discuss the process for TMDL development and describe the listed segments of Cub Creek, Turnip Creek, Buffalo Creek (UT), and the Staunton River. In addition, data and information collected was reviewed, and additional data needed for TMDL development was officially requested. Copies of the presentation materials were made available for public distribution. The meeting participants were contacted via email and phone by DEQ.

TAC Meeting No. 2 The second TAC meeting was held in the Town of Brookneal on September 29, 2005 to discuss the sources assessment and present the HSPF hydrology model calibration. Twelve people representing the various State and local government agencies attended this meeting. Copies of the presentation materials were made available for public distribution. The meeting participants were contacted via email and phone by DEQ.

Public Meeting No. 1. The first public meeting was held in the Town of Brookneal on September 7, 2004 to present: a review of the TMDL process; the listed segments of Cub Creek, Turnip Creek, Buffalo Creek (UT), and the Staunton River; the data that resulted in the 303d listing; inventories of livestock, wildlife, and pets; the fecal coliform sources assessment; the calculations used to estimate the total fecal coliform load; to explain the assumptions used in the calculations; and to present the HSPF model. Ten people attended the meeting. Copies of the presentation were made available for public distribution. Public notice for the meeting was reported in *The Virginia Register of Regulations*. During the 30-day comment period, no written comments were received.

Public Meeting No. 2. The Second public meeting will be held in the Town of Brookneal on January 23, 2006 to discuss the sources assessment, present the HSPF model calibration, and discuss the draft TMDL. Copies of the presentation and the executive summary of the Draft TMDL Report will be made available for public distribution. Public notice for the meeting was reported in *The Virginia Register of Regulations*.

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1.0 Introduction

1.1 Background

1.1.1 Regulatory Guidance

Section 303(d) of the Clean Water Act and the Environmental Protection Agency's (EPA's) Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for water bodies that are exceeding water quality standards. TMDLs represent the total pollutant loading that a water body can receive without violating water quality standards. The TMDL process establishes the allowable loadings of pollutants for a water body based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality based controls to reduce pollution from both point and non-point sources to restore and maintain the quality of their water resources (EPA, 2001).

The state regulatory agency for Virginia is the Department of Environmental Quality (DEQ). DEQ works in coordination with the Virginia Department of Conservation and Recreation (DCR), the Department of Mines, Minerals, and Energy (DMME), and the Virginia Department of Health (VDH) to develop and regulate a more effective TMDL process. DEQ is the lead agency for the development of TMDLs statewide and focuses its efforts on all aspects of reduction and prevention of pollution to state waters. DEQ ensures compliance with the Federal Clean Water Act and the Water Quality Planning Regulations, as well as with the Virginia Water Quality Monitoring, Information, and Restoration Act (WQMIRA, passed by the Virginia General Assembly in 1997), and coordinates public participation throughout the TMDL development process. The role of DCR is to initiate non-point source pollution control programs statewide using federal grant money. DMME focuses its efforts on issuing surface mining permits and National Pollution Discharge Elimination System (NPDES) permits for industrial and mining operations. Lastly, VDH monitors waters for fecal coliform, classifies waters for shellfish growth and harvesting, and conducts surveys to determine sources of bacterial contamination (DEQ, 2001a).

As required by the Clean Water Act and WQMIRA, DEQ develops and maintains a listing of all impaired waters in the state that details the pollutant(s) causing each impairment and the potential source(s) of each pollutant. This list is referred to as the 303(d) List of Impaired Waters. In addition to 303(d) List development, WQMIRA directs DEQ to develop and implement TMDLs for listed waters (DEQ, 2001a). Once TMDLs have been developed, they are distributed for public comment and then submitted to the EPA for approval.

1.2 Impairment Listing

Segments of Cub Creek, Turnip Creek and Staunton River were listed as impaired on Virginia's 1998 303(d) Total Maximum Daily Load Priority List and Report (DEQ, 1998) because of violations of the state's water quality standard for fecal coliform bacteria. These segments as well as a segment of Buffalo Creek (UT) were also included on Virginia's 2002 303(d) Report on Impaired Waters and 2004 305(b)/303(d) Water Quality Assessment Integrated Report. The impaired segments are located in the Lower Staunton River Basin in southwestern Virginia (**Figure 1-1**). The watershed is located in the hydrologic units (HUC) 03010101 and 03010102. The impaired watersheds include portions of Campbell, Charlotte, Halifax, Pittsylvania, and Appomattox counties.

The impaired segment of Cub Creek (VAC-L37R-01) extends for 14.21 miles from Big Cub Creek to Terry Creek. Eight out of 21 samples (38%) taken at ACUB010.96 between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100mL.

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The entire length of a Buffalo Creek (UT) (VAC-L40R-05) is impaired from the headwaters to Buffalo Creek. Five out of 10 samples (50%) collected at A4XMC000.54 between January 1, 1998 and December 31, 2002 exceeded the fecal coliform bacteria instantaneous criterion of 400 cfu/100mL.

In addition to the impaired segments on Cub Creek, Turnip Creek, Buffalo Creek (UT), this report also addresses an 80.46 mile segment of the Staunton River (VAC-L19R-01) including the Staunton River mainstem from Leesville Dam downstream to a pipeline crossing approximately 5.4 miles downstream of the Route 360 Bridge. The total length of these five impaired segments is 100.25 miles. **Table 1-1** summarizes the details of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton impaired segments and **Figure 1-1** presents their location.

Table 1-1 Details of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Bacteria Impairments

Segment ID	Segment Name	Upstream Boundary	Downstream Boundary	Length (Miles)	Initial Listing
VAC-L37R-01	Cub Creek	Big Cub Creek	Terrys Creek	14.21	2002
VAC-L36R-01	Turnip Creek	Buck Branch	Mouth at Staunton River	2.70	2002
VAC-L40R-05	Buffalo Creek (UT)	Headwaters	Buffalo Creek	2.88	2002
VAC-L19R-01	Staunton River	Leesville Dam	Pipeline Crossing approximately 5.4 miles downstream of the Route 360 Bridge	80.46	1998
VAC-L40R-03	Staunton River*	Pipeline crossing approximately 5.4 miles downstream of Route 360 bridge	Kerr Reservoir	4.49	1998

* Portions of these segments also do not support the Aquatic Life and Fish Consumption Uses; TMDLs for these impairments are being developed separately.
Source: Virginia 2004 Water Quality Assessment 305(b)/303(d) Integrated Report.

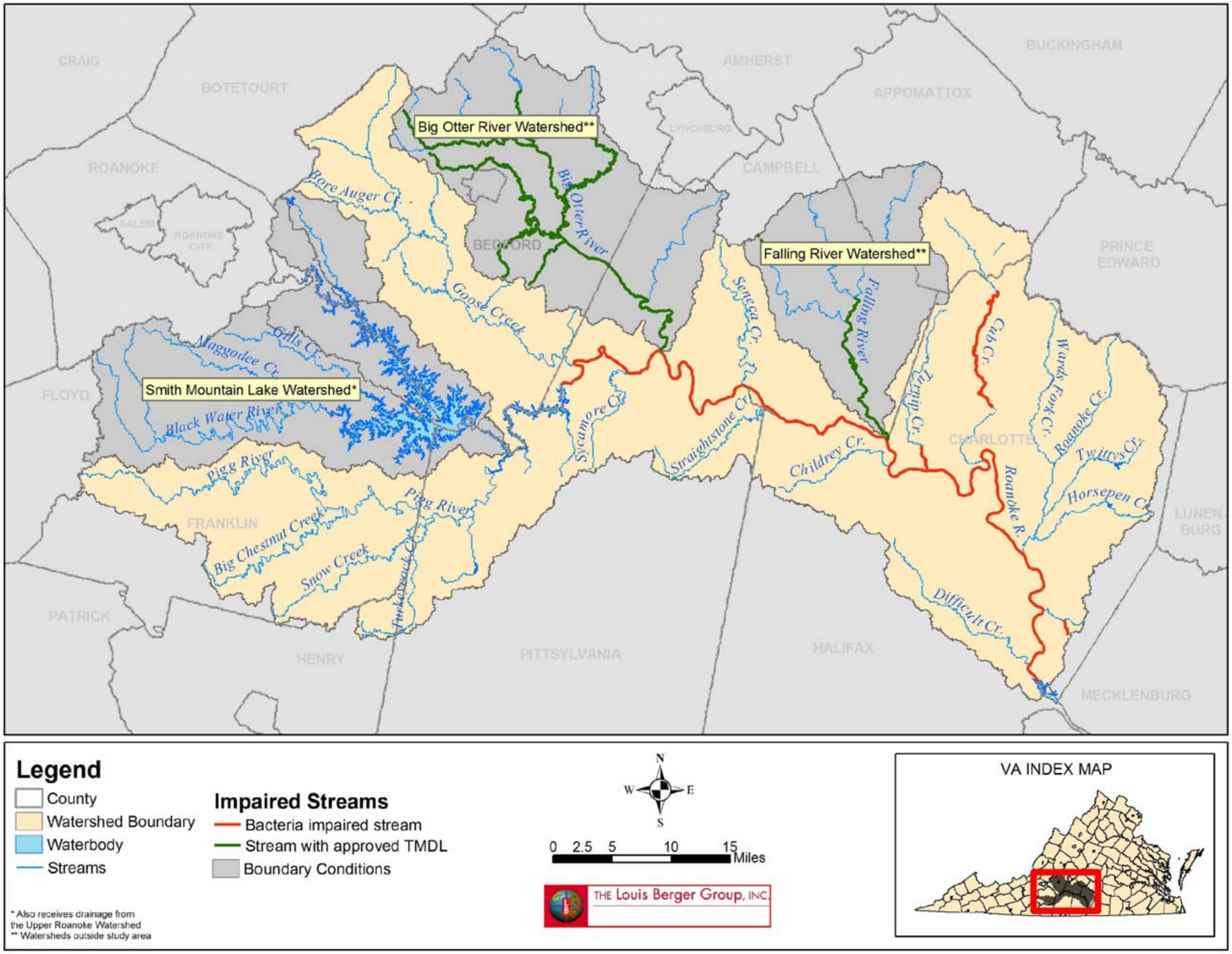


Figure 1-1: Location of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watersheds and Listed TMDL Segments

Virginia's 2004 305(b)/303(d) Water Quality Assessment Integrated Report identifies 52 other bacteria impairments in the study watershed in addition to the five impairments addressed in this report. These additional impairments are summarized in **Table 1-2**. Approved TMDLs for Falling River and Big Otter were included in developing the TMDLs presented in this report.

Table 1-2: Details of Additional Impairments in the Staunton River Watershed

Segment ID	Segment Name	Cause(s) of Impairment (Years Listed)	Length (Miles)	TMDL Status
VAC-L40R-05	Buffalo Creek, UT	Fecal Coliform (2002)	2.88	Scheduled for 2014
VAC-L04R-04	Ore Branch	Bacteria (1996)	2.42	Scheduled for 2006
VAC-L40R-03	Staunton River	Fecal Coliform (1998) Fish Tissue – PCBs (1998, 2002)	4.49	Scheduled for 2010
VAC-L37R-01	Cub Creek	Fecal Coliform (2002)	14.21	Scheduled for 2014
VAW-L02R-02	Wilson Creek	Bacteria (2002, 2004) Fish Tissue - PCBs (2002, 2004)	1.2	Scheduled for 2006
VAC-L36R-01	Turnip Creek	Bacteria (2002, 2004) Fish Tissue - PCBs (2002, 2004)	3.35	Scheduled for 2006
VAC-L19R-01	Staunton River	Fish Tissue – PCBs, Fecal Coliform (1998)	80.46	Scheduled for 2010
VAW-L04R-02	Staunton River	Bacteria (1996) General Standard (Benthic 1996) – 1.46 mi Fish Tissue - PCBs (2002)	2.24	Scheduled for 2006
VAW-L04R-01	Staunton River	Bacteria (1996) General Standard (Benthic 1996) Fish Tissue - PCBs (2002)	9.87	Scheduled for 2006
VAC-L28R-01	Big Otter Creek	Bacteria (1998)	13.98	Bacteria TMDL Approved 2/2/2001
VAW-L08R-01	Green Creek	Bacteria (1998) Temperature (2002)	3.93	Bacteria TMDL Approved 2/2/2001
VAC-L34R-01	Falling River	Fecal Coliform (1998)	17.92	Bacteria TMDL Approved 7/9/2004
VAW-L27R-01	Big Otter River, Falling Creek	Bacteria (2002 addition)	11.12	Bacteria TMDL Approved 2/2/2001
VAW-L26R-03	Machine Creek	Bacteria (1996)	11.33	Bacteria TMDL Approved 2/2/2001
VAW-L26R-01	Little Otter River	Bacteria (1996) Fish Tissue – PCBs (2002) General Standard (Benthic 2002)	27.03	Bacteria TMDL Approved 2/2/2001

Segment ID	Segment Name	Cause(s) of Impairment (Years Listed)	Length (Miles)	TMDL Status
VAW-L08R-02	South Fork of the Blackwater River Drainage	Bacteria (1996)	6.06	Bacteria TMDL Approved 2/2/2001
VAW-L08R-03	North Fork of the Blackwater River Drainage	Bacteria (1996) General Standard (1996)	12.25	Bacteria TMDL Approved 3/9/2001
VAW-L08R-04	Blackwater River Drainage	Bacteria (1996) General Standard (Benthic 1998)	43.83	Bacteria TMDL Approved 3/9/2001
VAW-L08R-05	Little Creek	Bacteria (2002) General Standard (Benthic 2002)	7.61	Bacteria TMDL Approved 12/4/2001
VAW-L08R-06	Teels Creek	Bacteria (2002) General Standard (Benthic 2002)	4.6	Bacteria TMDL Approved 12/4/2001
VAW-L09R-01	Maggodee Creek	Bacteria (1996) General Standard (Benthic 1996) – 7.38 mi	20.21	Bacteria TMDL Approved 4/27/2001
VAW-L09R-02	Mollie Branch	Bacteria (1998)	2.52	Bacteria TMDL Approved 4/27/2001
VAW-L11R-01	Gills Creek	Bacteria (1996)	22.25	Bacteria TMDL Approved 5/31/2002
VAW-L25R-01	Big Otter River, Elk Creek and North Otter Creek	Bacteria (1998)	37.48	Bacteria TMDL Approved 2/2/2001
VAW-L23R-01	Big Otter River, Sheeps Creek	Bacteria (1996)	17.49	Bacteria TMDL Approved 2/2/2001
VAW-L14R-02	Storey Creek	Bacteria (1996)	11.6	Scheduled for 2010
VAW-L15R-01	Big Chestnut Creek	Bacteria (2004)	12.88	Scheduled for 2016
VAW-L17R-01	Snow Creek	Bacteria (2002)	10.98	Scheduled for 2010
VAW-L18R-01	Pigg River	Bacteria (1998)	28.92	Scheduled for 2006
VAW-L20R-01	Goose Creek	Bacteria (2004)	6.79	Scheduled for 2016
VAW-L21R-01	Goose Creek	Bacteria (2004)	7.28	Scheduled for 2016
VAW-L22R-01	Goose Creek	Bacteria (2002)	10.04	Scheduled for 2014
VAW-L14R-01	Pigg River	Bacteria (1996)	35.06	Scheduled for 2006
VAW-L20R-01	Old Womans Creek	Bacteria (1998)	4.86	Scheduled for 2010
VAW-L07R-01	Beaverdam Creek	Bacteria (2002)	5.58	Scheduled for 2010
VAW-L06R-01	Back Creek	Bacteria (2004)	9.92	Scheduled for 2016
VAC-L31R-01	Seneca Creek	Fecal Coliform (2004)	9.1	Scheduled for 2016

Segment ID	Segment Name	Cause(s) of Impairment (Years Listed)	Length (Miles)	TMDL Status
VAC-L39R-01	Ash Camp Creek	General Standard (Benthic 1998) Fecal Coliform (2004	7.46	Scheduled for 2004
VAC-L39R-03	Horsepen Creek	Fecal Coliform (2002)	1.84	Scheduled for 2014
VAC-L39R-04	Wards Fork Creek	Fecal Coliform (2002)	5.73	Scheduled for 2014
VAC-L40R-01	Berles Creek	Fecal Coliform (2002)	2.18	Scheduled for 2014
VAC-L01R-01	Staunton River, South Fork	Bacteria (2004) Temperature (2004)	12.65	Scheduled for 2016
VAC-L40R-04	Sandy Creek	Fecal Coliform (2002)	3.34	Scheduled for 2014
VAC-L40R-06	Buffalo Creek	Fecal Coliform (2004)	2.34	Scheduled for 2016

Source: Virginia 2004 Water Quality Assessment 305(b)/303(d) Integrated Report.

1.3 Applicable Water Quality Standard

Water quality standards consist of designated uses for a water body and water quality criteria necessary to support those designated uses. According to Virginia Water Quality Standards (9 VAC 25-260-5), the term "water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."

1.3.1 Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10):

> *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

1.3.2 Applicable Water Quality Criteria

Effective January 15, 2003, DEQ specified a new bacteria standard in 9 VAC 25-260-170.A, and revised the disinfection policy in 9 VAC 25-260-170.B. These standards replaced the existing fecal coliform standard and disinfection policy of 9 VAC 25-260-170. For a non-shellfish supporting waterbody to be in compliance with Virginia bacteria standards for primary contact recreation, the current criteria are as follows:

> *"Fecal coliform bacteria shall not exceed a geometric mean of 200 fecal coliform bacteria per 100 ml of water for two or more samples taken over a calendar month nor shall more than 10% of the total samples taken during any calendar month exceed 400 fecal coliform bacteria per 100 ml of water. This criterion shall not apply for a sampling station after the [E. coli] bacterial indicators have a minimum of 12 data points or after June 30, 2008, whichever comes first."*

> *"E. coli bacteria shall not exceed a geometric mean of 126 bacteria per 100 ml of water for two or more samples taken during any calendar month nor should it exceed 235 counts per 100 ml of water for a single sample maximum value. No single sample maximum for E. coli shall exceed a 75% upper one-sided confidence limit based on a site-specific log standard deviation. If site data are insufficient to establish a site-specific log standard deviation, then 0.4 shall be used as the log standard deviation in freshwater. Values shown are based on a log standard deviation of 0.4 in freshwater."*

These criteria were adopted because there is a stronger correlation between the concentration of *E. coli* and the incidence of gastrointestinal illness than with fecal coliform. *E. coli* are bacteriological organisms that can be found in the intestinal tract of warm-blooded animals. Like fecal coliform bacteria, these organisms indicate the presence of fecal contamination.

For bacteria TMDL development after January 15, 2003, *E. coli* has become the primary applicable water quality target. However, the loading rates for watershed-based modeling are available only in terms of fecal coliform. Therefore, during the transition from fecal coliform to *E. coli* criteria, DCR, DEQ and EPA have agreed to apply a translator to in-stream fecal coliform data to determine whether reductions applied to the fecal coliform load would result in meeting in-stream *E. coli* criteria. The fecal coliform model and in-stream translator are used to calculate *E. coli* TMDLs. The following regression based instream translator is used to calculate *E. coli* concentrations from fecal coliform concentrations:

$$E.\ coli\ conc.\ (cfu/100\ ml) = 2^{-0.0172} \times [fecal\ coliform\ conc.\ (cfu/100ml)]^{0.91905}$$

For Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River impaired segments, each TMDL is required to meet both the geometric mean and instantaneous criteria. The modeled daily fecal coliform concentrations are converted to daily *E. coli* concentrations using the in-stream translator. The TMDL development process also must account for seasonal and annual variations in precipitation, flow, land use, and pollutant contributions. Such an approach ensures that TMDLs, when implemented, do not result in violations under a wide variety of scenarios that affect fecal coliform loading.

2.0 TMDL Endpoint Identification

2.1 Selection of TMDL Endpoint and Water Quality Targets

Four segments on Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River, located within Campbell, Charlotte, Halifax, and Appomattox counties in south-central Virginia, were initially placed on the 1996 303(d) list for violations of the fecal coliform standards for primary contact recreation. These five segments were also included on the 1998, 2002 and 2004 303(d) lists. The impaired segments comprise approximately 100.25 river miles.

One of the first steps in TMDL development is determining the numeric endpoints, or water quality targets, for each impaired segment. Water quality targets compare the current stream conditions to the expected restored stream conditions after TMDL load reductions are implemented. Numeric endpoints for the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDLs are established in Virginia Water Quality Standards (9 VAC 25-260). These standards state that all waters in Virginia should be free from any substances that can cause the water to violate the state numeric standards, interfere with its designated uses, or adversely affect human health and aquatic life. Therefore, the current water quality target for these four impairments, as stated in 9 VAC 25-260-170, is an *E. coli* geometric mean no greater than 126 colony-forming units (cfu) per 100 ml for two or more water quality samples taken during any calendar month, and a single sample maximum of 235 cfu per 100 ml at all times.

2.2 Critical Condition

The critical condition is considered the “worst case scenario” of environmental conditions in Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River. If the TMDL were developed such that the water quality targets are met under the critical condition, then the targets would also be met under all other conditions.

EPA regulations, 40 CFR 130.7 (c)(1), require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River is protected during times when it is most vulnerable.

Critical conditions are important because they describe the combination of factors to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards.

Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River flow through a predominantly rural setting, with forested and agricultural lands comprising the dominant land uses in the basin. Potential sources of fecal coliform include run-off from livestock grazing, manure applications, point source dischargers, and residential waste.

Fecal coliform loadings result from sources that can contribute during wet weather and dry weather. The critical conditions were determined from the available in-stream water quality data, the bacteria source tracking (BST) data collected by DEQ, and flow data obtained from USGS gauging stations located on each impaired segment.

Figure 2-1 depicts fecal coliform concentrations with the corresponding stream flow distribution at each of the impaired segments. **Figure 2-1** includes data from five water quality stations on the impaired segment of the Staunton River (4AROA059.12, 4AROA067.91, 4AROA097.46, 4AROA108.09, and 4AROA129.55), one station on Turnip Creek (4ATIP002.55), and one station on Cub Creek (4ACUB010.96). Fecal coliform data from the unique station on Buffalo Creek (4ABNN001.85) is not included in **Figure 2-1** since there no flow data associated with the fecal coliform observations were available. The data presented were collected from 1990 to 2003.

Plotting bacteria water-quality data along with available stream flow data (**Figure 2-1**) revealed that the largest violations were occurring predominantly during high flow conditions. This observation applies for Cub Creek, Turnip Creek, and Staunton River.

The depiction of E-coli concentrations versus flows confirms this observation where most of the exceedances occur during high flow and moderate flow conditions (**Figure 2-2**). However, most of the E-coli exceedances in Buffalo Creek (Station 4ABNN001.85), and a few exceedances in Turnip Creek (4ATIP002.55) and the upstream station of the Staunton River (Station 4AROA129.55) occurred during dry weather conditions.

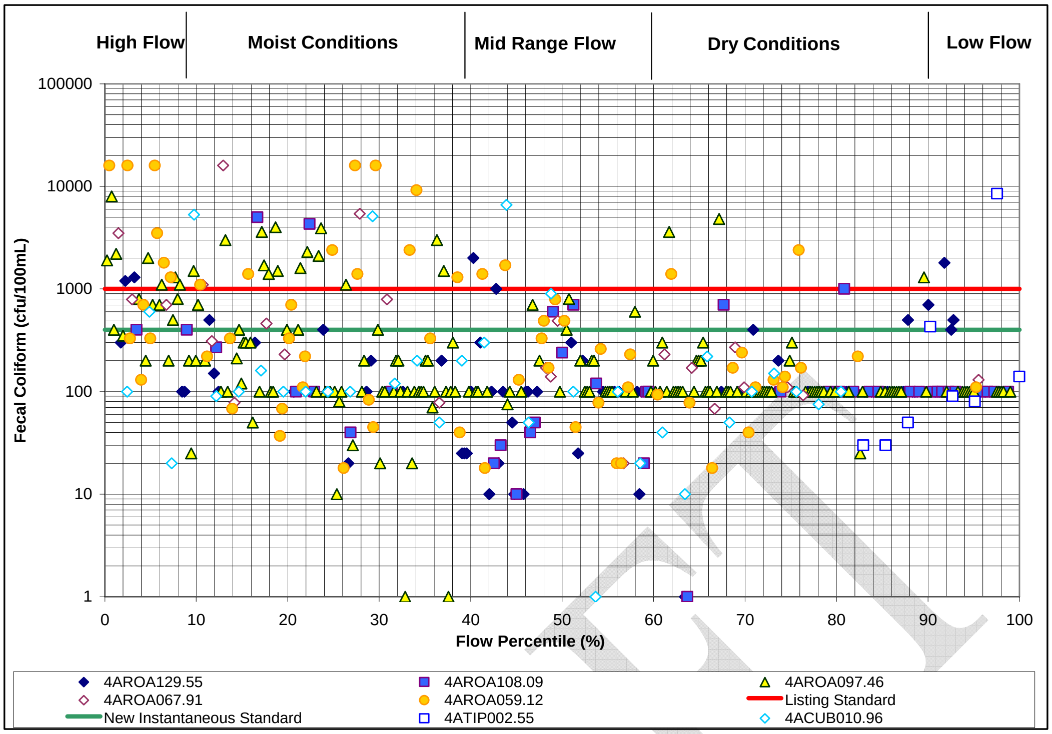


Figure 2-1: Flow Percentile and Fecal Coliform Concentrations

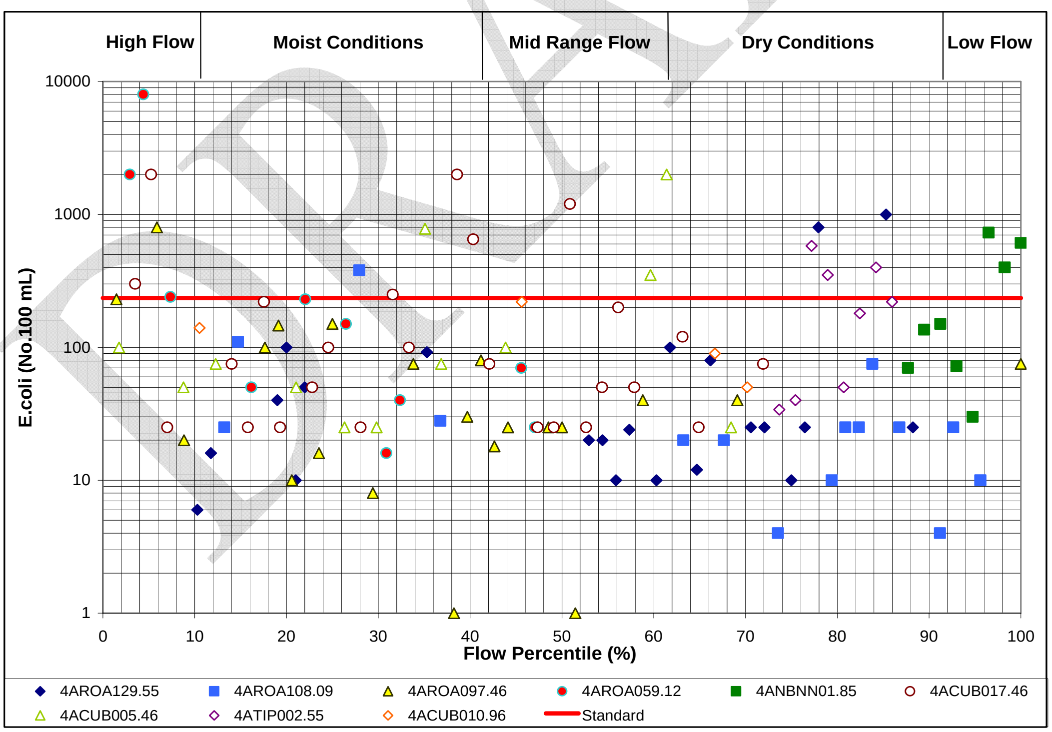


Figure 2-2: Flow Percentile and E. coli Concentrations

Consequently, high- and low-flow periods were considered in the critical condition because many of the observed violations occurred under these conditions. Violations under high-flow conditions would occur from indirect sources of bacteria, and would most likely exceed the instantaneous standard. Bacteria loads under low-flow conditions would likely occur from direct sources of bacteria, and would most likely violate the geometric mean standard.

This TMDL is required to meet both the geometric mean and instantaneous bacteria standards. Therefore, it is necessary for the critical condition to consider both wet weather, high flow conditions and dry weather, low flow conditions in order to comply with both the instantaneous and geometric mean bacteria standards.

2.3 Consideration of Seasonal Variations

Seasonal variations involve changes in stream flow and water quality because of hydrologic and climatological patterns. Seasonal variations were explicitly included in the modeling approach for this TMDL. The continuous simulation model developed for this TMDL explicitly incorporates the seasonal variations of rainfall, runoff and fecal coliform wash-off by using an hourly time-step. In addition, fecal coliform accumulation rates for each land use were developed on a monthly basis. This allowed the consideration of temporal variability in fecal coliform loading within the watershed.

3.0 Watershed Description and Source Assessment

In this section, the types of data available and information collected for the development of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDLs are presented. This information was used to characterize each stream and its watershed and to inventory and characterize the potential point and non-point sources of fecal coliform in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. Categories of data that were used include the following:

(1) Physiographic data that describe physical conditions (i.e., topography, soils, and land use) within the watershed

(2) Hydrographic data that describe physical conditions within the stream, such as the stream reach network and connectivity, and the stream channel depth, width, slope, and elevation

(3) Data related to uses of the watershed and other activities in the basin that can be used in the identification of potential fecal coliform sources

(4) Environmental monitoring data that describe stream flow and water quality conditions in the stream

Table 3-1 shows the various data types and the data sources used in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDLs.

Table 3-1: Inventory of Data and Information Used in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDL Development

Data Category	Description	Potential Source(s)
Watershed physiographic data	Watershed boundary	USGS, DEQ
	Land use/land cover	NLCD
	Soil data (SSURGO, STATSGO)	NRCS, BASINS
	Topographic data (USGS-30 meter DEM, USGS Quads)	USGS, DCR
Hydrographic data	Stream network and reaches (RF3)	BASINS, NHD, Field surveys
	Stream morphology	
Weather data	Hourly meteorological conditions	NCDC, Earth Info
Watershed activities/ uses data and information related to fecal coliform production	Information, data, reports, and maps that can be used to support fecal coliform source identification and loading	State, county, and city governments, local groups and stakeholders
	Livestock inventory, grazing, stream access, and manure management	DCR, local SWCDs, NRCS
	Wildlife inventory	DGIF
	Septic systems inventory and failure rates	Local Departments of Health, Utilities, U.S. Census Bureau
	Straight pipes	DEQ
	Best management practices (BMPs)	DCR, NRCS, local SWCDs
Point sources and direct discharge data and information	Permitted facilities locations and discharge monitoring reports (DMRs)	EPA Permit Compliance System (PCS), VPDES, DEQ
Environmental monitoring data	Ambient in-stream monitoring data	DEQ
	Stream flow data	USGS, DEQ

Notes
DCR: Virginia Department of Conservation and Recreation
DEQ: Virginia Department of Environmental Quality
DGIF: Virginia Department of Game and Inland Fisheries
EPA: Environmental Protection Agency
NCDC: National Climatic Data Center
NHD: National Hydrography Dataset
NLCD: National Land Coverage Data
NRCS: Natural Resources Conservation Service
SWCD: Soil and Water Conservation District
USGS: U.S. Geological Survey
VPDES: Virginia Pollutant Discharge Elimination System

3.2 Watershed Description and Identification

3.2.1 Watershed Boundaries

The impaired segment of the Staunton River begins in Campbell County and flows through the borders of Campbell and Pittsylvania Counties into the borders of Halifax and Charlotte Counties. Cub Creek, Turnip Creek, and Buffalo Creek (UT) are tributaries to the Staunton River and are located in Charlotte County. All four streams are located in the Staunton River Basin (USGS Cataloging Unit 03010101 and 03010102). The watershed that encompasses the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River bacteria impairments is approximately 1,477,287 acres or 2,308 square miles. The watershed drains portions of Bedford, Franklin, Henry, Campbell, Pittsylvania, Appomattox, Charlotte, and Halifax counties.

Bacteria TMDLs have already been approved for six impaired streams in the watershed: Machine Creek, Elk Creek, Sheep Creek, Little Otter River, Big Otter River and Falling River. The first five impairments all flow into Big Otter River, which then flows into the Staunton River just upstream of the Campbell County/Pittsylvania County line. The last impairment flows through Falling River into the Staunton River at the border of Campbell, Charlotte, and Halifax Counties. The TMDL developed for this study will include the results of the bacteria TMDLs developed for the Big Otter River and the Falling River watersheds.

Approximately 24 percent of the drainage basin is located in the Bedford County. A small portion of the watershed is located in Appomattox and Henry Counties (4.5 and 0.5 percents respectively). The remainder of the watershed is divided among Campbell, Charlotte, Franklin, Pittsylvania, and Halifax Counties (19, 18, 12, 11, and 11 percent, respectively). The watershed makes up 100 percent of the land area in the Bedford City, 89 percent of Charlotte County, 86 percent of Campbell County, 72 percent of Bedford County, 37 percent of Franklin County, 30 percent each of Halifax and Appomattox Counties, 27 percent of Pittsylvania County, and three percent of Henry County. Interstates 81 and 581 are located to the west of the watershed. U.S. highways 29, 220, and 501 run generally from North to South through the watershed and U.S. highways 460 and 221 run through the North-West section of the watershed. **Figure 3-1** is a map showing the location, roads, and boundary of the watershed.

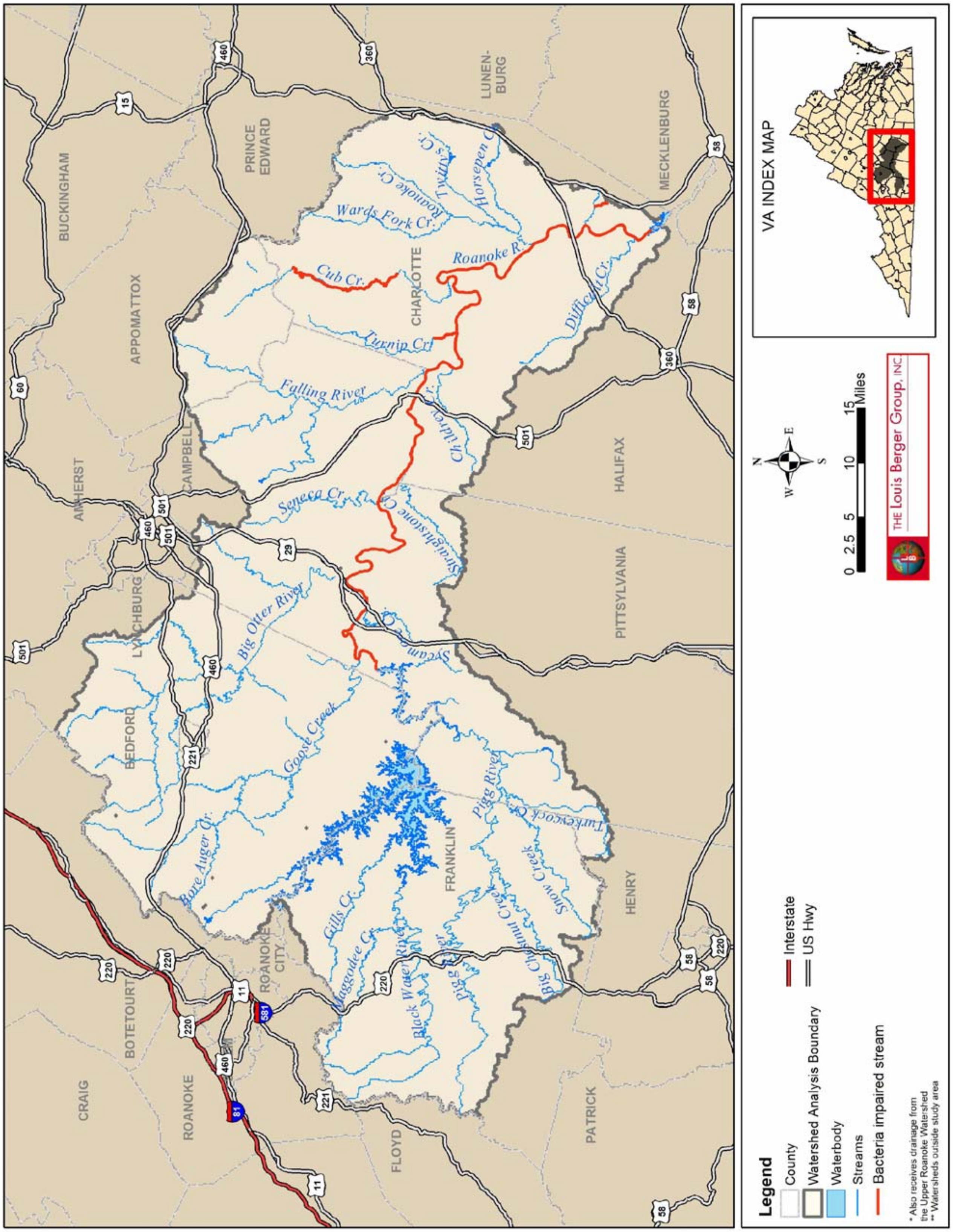


Figure 3-1: Location and Boundary of Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watershed

3.2.2 Topography

A digital elevation model (DEM) based on USGS National Elevation Dataset (NED) was used to characterize topography in the watershed. NED data were obtained from The National Map Seamless Data Distribution System maintained by the USGS Eros Data Center. Elevation in the watershed ranges from 86 to 1,289 meters (282 to 4,229 feet) above mean sea level.

3.2.3 Soils

The Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed soil characterization was based on STASGO data obtained from BASINS. There are thirteen general soil associations located in the watershed (see **Table 3-2**). The four dominant soil types in the watershed are the Cecil-Madison (VA019), Hayesville-Parker Peeks (VA007), Georgeville-Nason-Lignum (VA045), Cullen-Wilkes-Iredell (VA031) and Nason-Manteo-Goldston (VA014). The distribution of soils in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed is presented in **Table 3-2**.

Table 3-2: Soil Types and Characteristics in the Cub Creek, Turnip Creek, Buffalo Creek and Staunton River Watershed

ap Unit ID	Soil Association	Dominating Hydrologic Soil Group	Percent Area
VA005	Wallen-Dekalb-Drypond	B/C	0.17%
VA007	Hayesville-Parker-Peaks	B	9.62%
VA014	Nason-Manteo-Goldston	C	6.03%
VA016	Shottower-Laidig_Weikert	B/C	0.04%
VA017	Groseclose-Litz-Shottower	C	0.66%
VA019	Cecil-Madison	B	56.78%
VA020	Rubble Land-Porters-Hayesville	A/B	0.29%
VA029	Iredell-Poindexter-Pacolet	B/C/D	2.64%
VA030	Appling-Wedowee-Louisburg	B	3.95%
VA031	Cullen-Wilkes-Iredell	C	6.51%
VA032	Chewacla-Congaree-Wehadkee	B/C/D	1.21%
VA042	Mayodan-Creedmoor-Pinkston	B/C	3.07%
VA045	Georgeville-Nason-Lignum	B	9.04%
		Total	100%

Source: STASGO

The hydrologic soil group linked with each soil association is also presented in Table 3-2. The hydrologic soil groups represent different levels of infiltration capacity of the soils. Hydrologic soil group "A" designates soils that are well to excessively well drained, whereas hydrologic soil group "D" designates soils that are poorly drained. This means that soils in hydrologic group "A" allow a larger portion of the rainfall to infiltrate and become part of the ground water system. On the other hand, compared to the soils in hydrologic group "A", soils in hydrologic group "D" allow a smaller portion of the rainfall to infiltrate and become part of the ground water. Consequently, more rainfall becomes part of the surface water runoff. Descriptions of the hydrologic soil groups are presented in **Table 3-3**.

Table 3-3: Descriptions of Hydrologic Soil Groups

Hydrologic Soil Group	Description
A	High infiltration rates. Soils are deep, well drained to excessively drained sand and gravels.
B	Moderate infiltration rates. Deep and moderately deep, moderately well and well-drained soils with moderately coarse textures.
C	Moderate to slow infiltration rates. Soils with layers impeding downward movement of water or soils with moderately fine or fine textures.
D	Very slow infiltration rates. Soils are clayey, have high water table, or shallow to an impervious cover

3.2.4 Land Use

Land use characterization was based on National Land Cover Data (NLCD) developed by USGS. Land use was calculated for the study area and does not include the Big Otter, Falling River, or Smith Mountain Lake drainage areas. The distribution of land uses in Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed, by land area and percentage, is presented in **Table 3-4**. Dominant land uses in the watershed are forested land (70%) and agricultural land (24%), which account for a combined 94% of the total land area in the watershed. Brief descriptions of land use classifications are presented in **Table 3-5.**

Table 3-4: NLCD Land Use within the Cub Creek, Turnip Creek, Buffalo Creek (UT) and Staunton River Watersheds

Land Use Category	NLCD Land Use Type	Acres		Percent of Watershed's Land Area	
Water/ Wetlands	Open Water	8,814	32,710	0.8%	3%
	Woody Wetlands	21,709		2.0%	
	Emergent Herbaceous Wetlands	2,187		0.2%	
Urban	Low Intensity Residential	7,633	9,553	0.7%	1%
	High Intensity Residential	11		0.0%	
	Commercial/Industrial/Transportation	1,910		0.2%	
Agriculture	Pasture/Hay	231,605	261,726	21.5%	24%
	Row Crops	30,120		2.8%	
Forest	Deciduous Forest	479,253	754,889	44.4%	70%
	Evergreen Forest	110,133		10.2%	
	Mixed Forest	165,504		15.4%	
Other	Quarries/Strip Mines/Gravel Pits	743	19,649	0.1%	2%
	Transitional	18,758		1.7%	
	Urban/Recreational Grasses	149		0.0%	
Total		1,078,527		100%	
Source: Multi-Resolution Land Characteristics Consortium (NLCD)					

Table 3-5: Descriptions of Land Use Types

Land Use Type	Description
Open Water	Areas of open water, generally with less than 25 percent or greater cover of water.
Woody Wetlands	Areas where forest or shrubland vegetation accounts for 25-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Emergent Herbaceous Wetlands	Areas where perennial herbaceous vegetation accounts for 75-100 percent of the cover and the soil or substrate is periodically saturated with or covered with water.
Low Intensity Residential	Includes areas with a mixture of constructed materials and vegetation. Constructed materials account for 30-80 percent of the cover. Vegetation may account for 20 to 70 percent of the cover. These areas most commonly include single-family housing units. Population densities will be lower than in high intensity residential areas.
High Intensity Residential	Includes heavily built up urban centers where people reside in high numbers. Examples include apartment complexes and row houses. Vegetation accounts for less than 20 percent of the cover. Constructed materials account for 80-100 percent of the cover.
Commercial/ Industrial/ Transportation	Includes infrastructure (e.g. roads, railroads, etc.) and all highways and all developed areas not classified as High Intensity Residential.
Pasture/Hay	Areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops.
Row Crop	Areas used for the production of crops, such as corn, soybeans, vegetables, tobacco, and cotton.
Deciduous Forest	Areas dominated by trees where 75 percent or more of the tree species shed foliage simultaneously in response to seasonal change.
Evergreen Forest	Areas characterized by trees where 75 percent or more of the tree species maintain their leaves all year. Canopy is never without green foliage.
Mixed Forest	Areas dominated by trees where neither deciduous nor evergreen species represent more than 75 percent of the cover present.
Quarries/Strip Mines/Gravel Pits	Areas of extractive mining activities with significant surface expression.
Transitional	Areas of sparse vegetative cover (less than 25 percent that are dynamically changing from one land cover to another, often because of land use activities. Examples include forest clearcuts, a transition phase between forest and agricultural land, the temporary clearing of vegetation, and changes due to natural causes (e.g. fire, flood, etc.)
Urban/Recreational Grasses	Vegetation (primarily grasses) planted in developed settings for recreation, erosion control, or aesthetic purposes. Examples include parks, lawns, golf courses, airport grasses, and industrial site grasses.

Source: Multi-Resolution Land Characteristics Consortium NLCD

Figure 3-2 depicts the land use distribution within the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. The watershed is predominantly forested with agricultural lands distributed throughout the watershed. The majority of the urban and residential areas are located near the cities of Bedford, Altavista, and Rocky Mount.

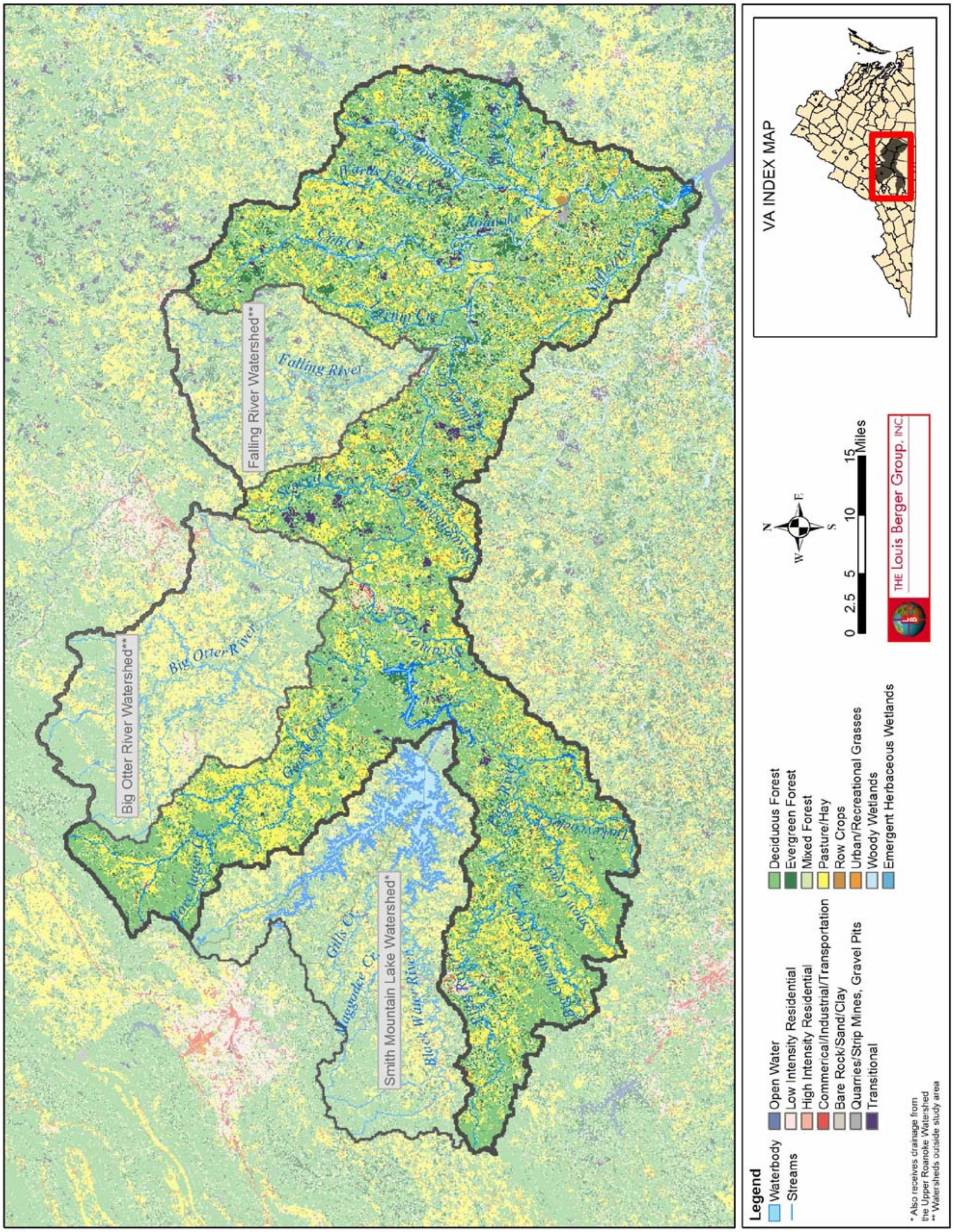


Figure 3-2: Land Use in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watershed

3.3 Stream Flow Data

Stream flow data for the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed was retrieved from six U.S. Geological Survey (USGS) stream flow gauging stations and is summarized in **Table 3-6**. The location of these flow gauging stations is presented in **Figure 3-3**. Flow data from Smith Mountain Lake was acquired from the Altavista hydroelectric power plant. The location of this facility is shown in **Figure 3-14**. Stream flow data obtained from these sources were used in the set-up, hydrological calibration, and validation of the model.

Table 3-6: USGS Stream Flow Gauging Stations in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watersheds

Station ID	Station Name	Area (mi^2)	Begin Date	End Date	No. of Records
02058400	Pigg River near Sandy Level, VA	350	06/01/1963	04/30/2005	15,303
02059500	Goose Creek near Huddleston, VA	188	10/01/1930	04/30/2005	27,241
02060500	Staunton River at Altavista, VA	1,789	10/01/1930	04/30/2005	27,241
02061500	Big Otter River near Evington, VA	320	04/01/1937	04/30/2005	24,866
02062500	Staunton River at Brookneal, VA	2,415	10/01/1923	04/30/2005	29,798
02064000	Falling River near Naruna, VA	173	10/01/1929	04/30/2005	25,049
02065500	Cub Creek at Phenix, VA	98	10/01/1946	04/30/2005	21,394
02066000	Staunton River at Randolph, VA	2,977	10/01/1901	04/30/2005	22,492

Source: USGS Daily Stream flow for the Nation

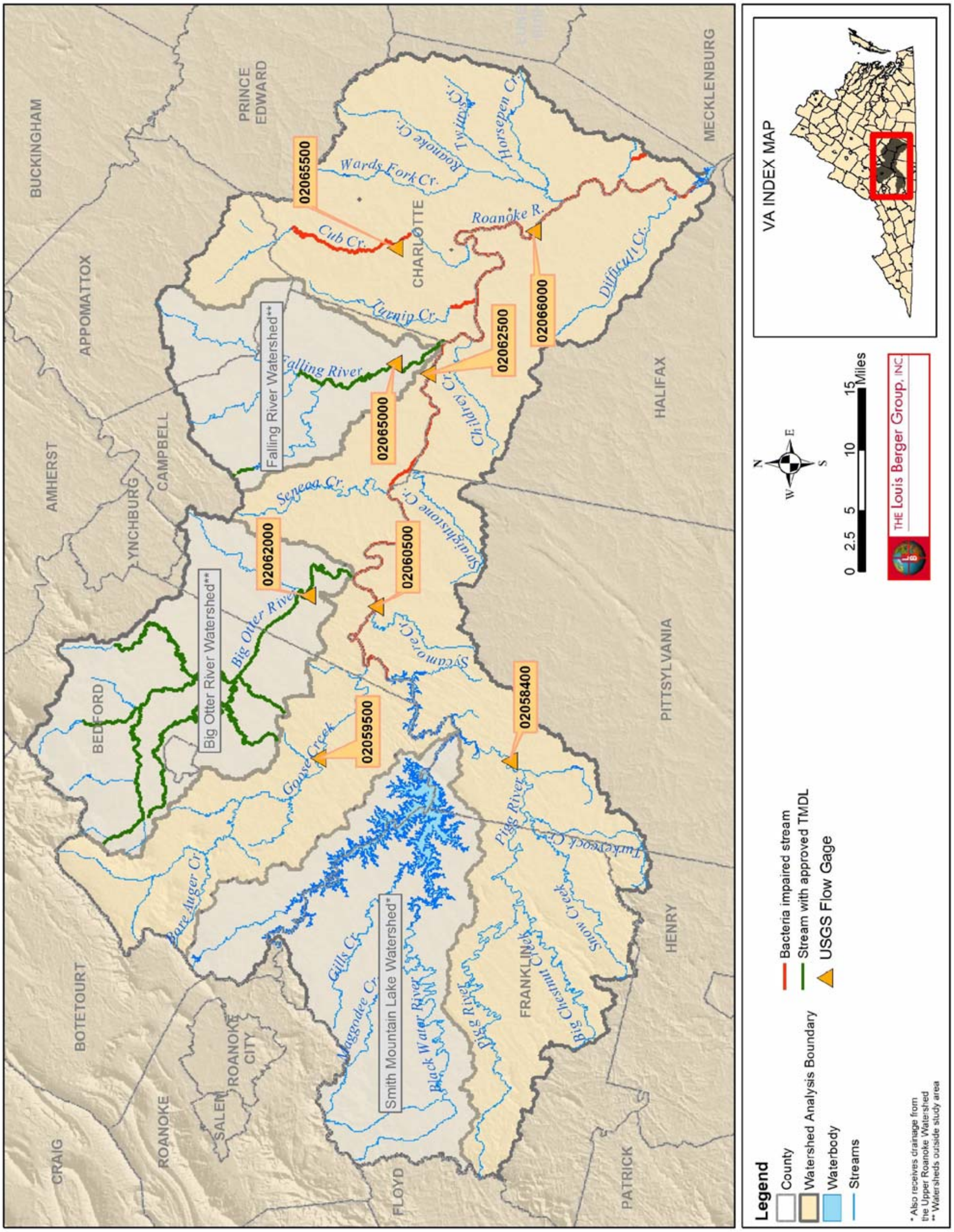


Figure 3-3:USGS flow Stations in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watershed

3.4 In-Stream Water Quality Conditions

Water quality data for the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed was obtained from DEQ, which conducted sampling at 111 water quality monitoring stations located within the study area. Locations of these stations are summarized in **Table 3-7**. **Figure 3-4** depicts the locations of these monitoring stations.

Table 3-7: Water Quality Monitoring Stations within the Cub Creek, Turnip Creek, Buffalo Creek and Staunton River Watersheds

No.	Station ID	Station Description	Stream Name	County
1	4AACC001.15	Ash Camp Cr 1.15 mi above Staunton Creek	Ash Camp Creek	Charlotte
2	4AACC001.75	0.85 miles downstream of Rt 654 bridge	Ash Camp Creek	Charlotte
3	4AACC002.60	Route 654 Bridge	Ash Camp Creek	Charlotte
4	4AACC004.87	Ash Camp Cr @Private Rd	Ash Camp Creek	Charlotte
5	4AATD003.36	Armistead Br E of Rt 627	Armistead Branch	Halifax
6	4ABCD001.70	Buckskin Cr @ Route 624	Buckskin Creek	Halifax
7	4ABES001.21	Berles Cr. @ Route 631, DSS Vaughan Farm	Berles Creek	Charlotte
8	4ABHA002.47	RTE 639 (Rockbarn Road)	Buffalo Creek	Halifax
9	4ABNN001.85	Buffalo Creek at Route 608, near Red Oak, Va.	Buffalo Creek	Charlotte
10	4ABUB000.06	Big Cub Creek @ Route 701	Big Cub Creek	Charlotte
11	4ABUB006.50	Route 675	Big Cub Creek	Appomattox
12	4ABWC001.00	Route 600	Black Walnut	Halifax
13	4ACAR001.70	Cargills Creek Rd	Cargills Creek	Charlotte
14	4ACBA000.22	Route 626	Catawba Creek	Halifax
15	4ACNT001.32	RT. 715 Bridge	Chestnut Creek	Franklin
16	4ACNT012.10	McNeil Mill Rd. (Route 718)	Chestnut Creek	Franklin
17	4ACOR000.21	Below Burlington - Brookneal Outfall	Corporation Branch	Campbell
18	4ACRE002.52	Route 632 Bridge	Childry Creek	Halifax
19	4ACTO001.01	Off Route. 761 near Canton Creek Church	Canton Creek	Franklin
20	4ACUB002.21	Route 649 (Coles Ferry Road)	Cub Creek	Charlotte
21	4ACUB005.46	Route 619 (Cub Creek Church Rd)	Cub Creek	Charlotte
22	4ACUB010.96	Cub Creek near Rt.40 gauging station	Cub Creek	Charlotte
23	4ACUB017.46	Red House Road	Cub Creek	Charlotte
24	4ADFF002.02	Route 716 Bridge	Difficult Creek	Halifax
25	4ADFF004.90	Difficult Cr. @ Route 720, DSS Brian	Difficult Creek	Halifax
26	4ADFF009.01	Difficult Cr. @ Route 360, USS Brian	Difficult Creek	Halifax
27	4ADOE002.47	Route 720 Bridge	Doe Run	Franklin
28	4AEIS002.07	Down from Cook Lane, South of Route 784	Ellis Creek	Halifax
29	4AFRY006.08	Route 40 Bridge	Fryingpan Creek	Pittsylvania

No.	Station ID	Station Description	Stream Name	County
30	4AFRZ000.20	Business Route 29, Altavista	Fraziers Creek	Campbell
31	4AGSE000.20	Route 630 Bridge at Leesville	Goose Creek	Campbell
32	4AGSE013.78	At gage near Huddleston	Goose Creek	Bedford
33	4AGSE022.55	Route 24 Bridge at gage	Goose Creek	Bedford
34	4AGSE025.64	Route 747 Bridge at Joppa Mill	Goose Creek	Bedford
35	4AGSE037.78	Station #22 Route 755 Bridge	Goose Creek (Upper)	Bedford
36	4AGSF002.16	Route 607 Bridge below Fuel Storage, Montvale	Goose Creek South Fork	Bedford
37	4AHEN002.16	Route 637 Bridge	Horsepen Creek	Charlotte
38	4AHEN004.74	Above Route 612	Horsepen Creek	Charlotte
39	4AHPN001.62	Route 785 Bridge	Harpen Creek	Pittsylvania
40	4AHTA000.77	Route 617	Hunting Creek	Halifax
41	4AHTA003.26	Station 1- Conner Lake (portion of Hunting Creek)	Hunting Creek	Halifax
42	4ALHT000.70	Route 668 (Level Run Road)	Little Straig	Pittsylvania
43	4ALNF002.18	Below Franklin County Landfill	North Fork Little Chestnut Creek	Franklin
44	4ALNF002.57	Above Franklin County Landfill	North Fork Little Chestnut Creek	Franklin
45	4ALNT001.00	Off of Route 810 near Sydnorsville	Little Chestnut Creek	Franklin
46	4ALOU001.16	Route 619 (Aspen Wall Road)	Louse Creek	Charlotte
47	4ALRO003.34	Route 47 Bridge	Little Roanoke Creek	Charlotte
48	4ALRO006.42	Route 40 Bridge	Little Roanoke Creek	Charlotte
49	4ALUB000.12	Route 691 (Tower Rd/Thortons Mill Rd)	Little Cub Creek	Charlotte
50	4AMFK000.52	East of US Route 220 and Route 618, Franklin	Muddy Fork	Franklin
51	4AOWC002.35	Paisley Rd. (Route 756)	Old Womans Creek	Pittsylvania
52	4AOWC004.37	Below Route 940 Near Owens Mill Hunt Club	Old Womans Creek	Pittsylvania
53	4AOWC005.36	STA #17 Route 760 Bridge	Old Womans Creek	Pittsylvania
54	4APAA000.24	LaPrade farm below Route 629	Poplar Branch	Franklin
55	4APGG003.29	Route 605 Bridge	Pigg River	Pittsylvania
56	4APGG008.42	Route 40 Bridge, near gauging station	Pigg River	Pittsylvania
57	4APGG008.87	Off Route 40 at USGS gage	Pigg River	Pittsylvania
58	4APGG016.06	Route 626 Bridge	Pigg River	Pittsylvania
59	4APGG030.62	Route 646 Bridge	Pigg River	Franklin
60	4APGG052.73	Route 713 Bridge Upstream Rocky Mountain STP	Pigg River	Franklin
61	4APGG055.72	Route 220 Bypass Below Rocky Mountain STP	Pigg River	Franklin
62	4APGG057.85	Route 220 Bridge above Rocky Mountain STP	Pigg River	Franklin
63	4APGG068.49	Route 756 Bridge	Pigg River	Franklin

No.	Station ID	Station Description	Stream Name	County
64	4APGG074.87	Station #18 Route 908 Ford	Pigg River	Franklin
65	4AROA048.32	John H. Kerr Reservoir, approx. 1/4 mile Above Staunton River	Staunton River	Charlotte
66	4AROA059.12	Route 360 Bridge, East of Clover	Staunton River	Charlotte
67	4AROA067.91	Route 746 Bridge (Watkins Bridge)	Staunton River	Halifax
68	4AROA090.50	Route 620 South of Brookneal	Staunton River	Halifax
69	4AROA097.07	Route 501 at Brookneal	Staunton River	Campbell
70	4AROA097.46	Staunton River at Brookneal Gage, Route 50	Staunton River	Campbell
71	4AROA107.84	Above Brookneal, Route 761 Bridge	Staunton River	Pittsylvania
72	4AROA108.09	Route 761 Bridge, Main Channel of Staunton River	Staunton River	Campbell
73	4AROA124.59	Route 640 Bridge	Staunton River	Pittsylvania
74	4AROA128.98	Route 668 Bridge at Altavista	Staunton River	Campbell
75	4AROA129.55	Route 29 Bridge at gage	Staunton River	Pittsylvania
76	4AROA131.55	Route 29 Bridge Bypass, Altavista	Staunton River	Pittsylvania
77	4AROA134.35	South of Route 43 and above Altavista	Staunton River	Pittsylvania
78	4AROA140.66	Leesville Lake #1A-Top #1B-Middle #1C-Bottom	Staunton River	Pittsylvania
79	4AROA145.34	Leesville Lake #2A	Staunton River	Bedford
80	4AROA153.59	Leesville Lake #3A	Staunton River	Pittsylvania
81	4AROC001.00	Roanoke Cr. @ Roanoke Station Rd.	Roanoke Creek	Charlotte
82	4AROC005.35	Roanoke Creek at Roanoke Station Road	Roanoke Creek	Charlotte
83	4ASCE000.26	At the Confluence With Twittys Creek	Sycamore Creek	Pittsylvania
84	4ASDA000.67	Davis Mill Bridge	Story Creek	Franklin
85	4ASDA007.24	Route 40 Bridge near Ferrum	Story Creek	Franklin
86	4ASDA009.77	Off Route 864 Below Ferrum STP Outfall	Story Creek	Franklin
87	4ASDA009.79	Route 623 Bridge above Ferrum STP Outfall	Story Creek	Franklin
88	4ASDA010.16	Route 40 Bridge at Ferrum below FJ College	Story Creek	Franklin
89	4ASEN000.40	Route 704 Bridge above Long Island	Seneca Creek	Campbell
90	4ASLA001.52	Sandy Creek @ Route 608	Sandy Creek	Charlotte
91	4ASLA002.69	Sandy Cr. @ Route 607	Sandy Creek	Charlotte
92	4ASNW000.60	Kirby Ford Bridge	Snow Creek	Pittsylvania
93	4ASNW010.08	Route 651	Snow Creek	Franklin
94	4ASRN005.14	Keysville Reservoir (Lake)	Spring Creek	Charlotte
95	4ASSC002.98	Route 761 (Straightstone Road)	Straightstone	Pittsylvania
96	4ATCC003.71	Danville Turnpike near Sago (Route 969)	Turkeycock Cr	Pittsylvania
97	4ATIP002.55	Turnip Creek, Route 619 Bridge	Turnip Creek	Charlotte
98	4ATIP008.76	Route 40	Turnip Creek	Charlotte
99	4ATIP013.21	Route 756 (Wren Road)	Turnip Creek	Charlotte
100	4ATMA001.46	Route 644 Bridge	Tomahawk Cree	Pittsylvania
101	4ATMA004.60	Burton Lake (at Dam)	Tomahawk Cree	Pittsylvania
102	4ATWT000.32	Twittys Creek at Sylvan Hill Road	Twittys Creek	Charlotte

No.	Station ID	Station Description	Stream Name	County
103	4ATWT006.40	Station 1 - Route 47 Bridge	Twittys Creek	Charlotte
104	4ATWT009.63	SCS Roanoke Creek Watershed Dam #72A	Twittys Creek	Charlotte
105	4ATYS001.25	Terrys Creek @ Stockdale Rd	Terrys Creek	Charlotte
106	4AWFC002.12	Wards Fork Creek, Route 645 Bridge	Wards Fork Creek	Charlotte
107	4AWLF000.09	Route 691 Bridge at Joppa Mill	Wolf Creek	Bedford
108	4AWMB001.07	Middle Br. Wards Fork @ Virginian	Wards Fork Creek	Charlotte
109	4AWPP002.53	Route 633	Whipping Creek	Campbell
110	4AXMC000.54	UT Buffalo @ Route 605	Buffalo Creek (UT)	Charlotte
111	4AXUP000.06	Upstream of Route 698 Crossing E. Lit	Little Seneca	Campbell

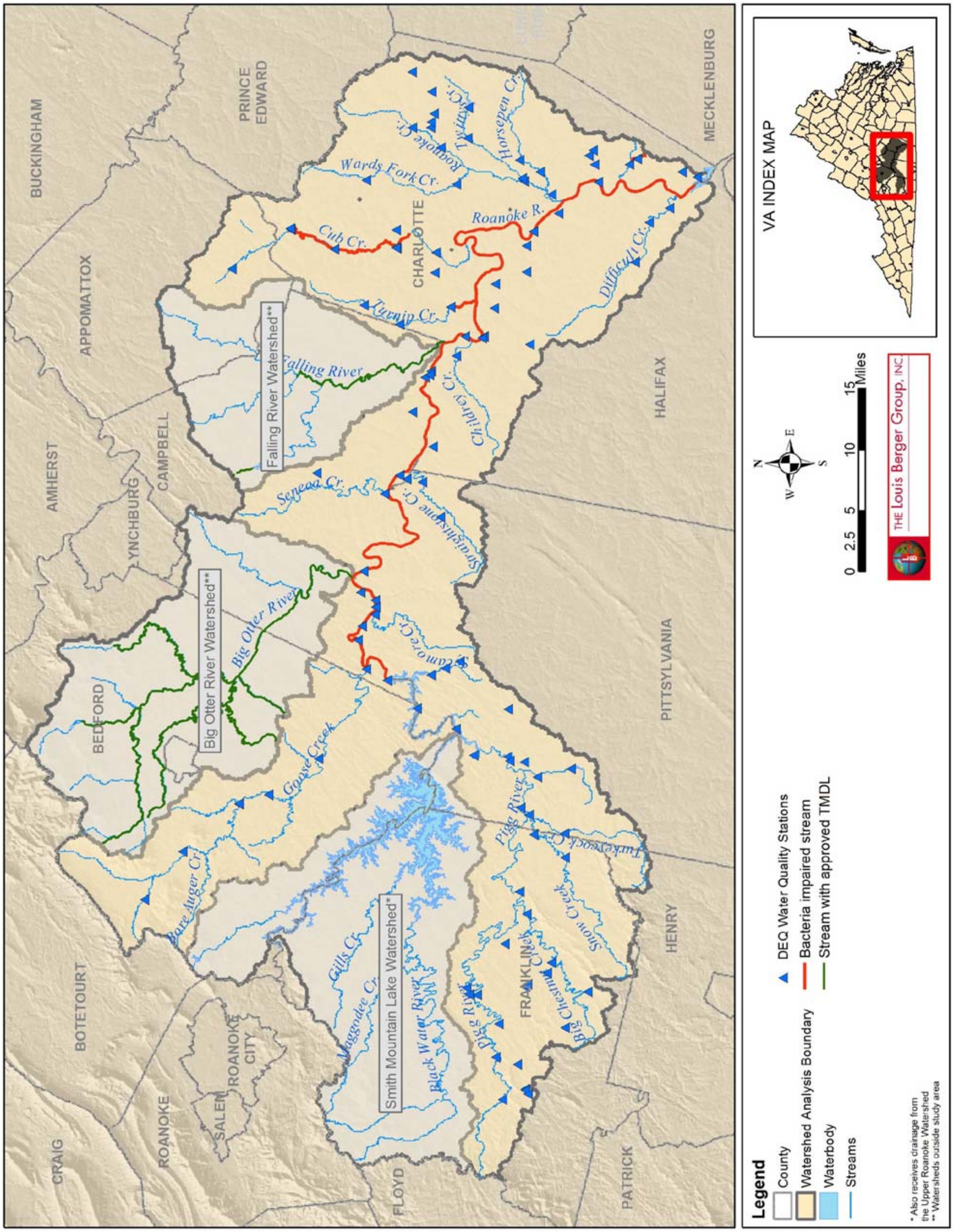


Figure 3-4: DEQ Water Quality Monitoring Stations

Between 1990 and 2005, 62 out of the 111 water quality stations within the study area, were recorded as exceeding the fecal coliform instantaneous standard and 22 stations were recorded as exceeding the geometric mean standard. **Table 3-8** lists the water quality sampling period of record, the number of samples collected, the minimum, maximum, and average concentrations observed, and the number and percentage of samples violating the water quality standard. Water quality data collected from the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River listing stations are highlighted in yellow in **Table 3-8**. Water quality data collected within the study area indicate that violation of the fecal coliform standard ranged from 3 to 100 percent for the instantaneous maximum criterion of 400 cfu/100 ml, and from 1 to 26 percent for the geometric mean criterion of 200 cfu/100 ml (**Table 3-9**).

Out of the 111 DEQ water quality stations located within the study area, 64 stations were recorded as exceeding the E. coli instantaneous standard. In addition, 19 of these stations also exceeded the geometric mean standard. Water quality data collected within the study area indicated that exceedence of the E. coli standard ranged from 7 to 100 percent for the instantaneous maximum criterion of 235 counts/100 ml, and from 4 to 25 percent for the geometric mean criterion of 195 counts/100 ml (**Table 3-9**). Over 12 E. coli samples were taken at 27 stations within the watershed. According to the VA DEQ Water Quality Standards (2003), the criterion of E. coli will apply for a sampling station until 12 data points are collected.

3-8: Summary of DEQ Fecal Coliform Bacteria Sampling Events that Exceeded the Water Quality Standards within the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River Watersheds.

No.	Station	No of Samples Collected Between 1990-2005	Sample Value (cfu/100ml)			Exceedances of WQS			
						Inst. Max[1]		Geo. Mean[2]	
			Min	Max	Average	No.	%	No.	%
1	4AACC001.15	4	18	460	144	1	25	-	-
2	4AACC001.75	1	2000	2000	2000	1	100	-	-
3	4AACC002.60	2	100	2100	1100	1	50	-	-
4	4AACC004.87	1	500	500	500	1	100	-	-
5	4ABES001.21	11	20	5400	1005	5	45	-	-
6	4ABNN001.85	12	60	6600	946	5	42	-	-
7	4ACNT001.32	22	100	2300	255	2	9	-	-
8	4ACNT012.10	6	25	450	159	1	17	-	-
9	4ACOR000.21	28	100	700	136	2	7	-	-
10	4ACRE002.52	21	100	800	133	1	5	-	-
11	4ACUB010.96	54	1	16000	1373	10	19	1	2
12	4ADFF002.02	34	100	500	153	1	3	-	-
13	4ADFF009.01	12	20	9200	913	2	17	-	-
14	4ADOE002.47	12	100	2100	392	3	25	-	-
15	4AFRZ000.20	36	100	2300	331	8	22	-	-
16	4AGSE000.20	48	100	6700	469	7	15	1	2
17	4AGSE022.55	30	100	3100	470	7	24	-	-
18	4AGSE037.78	32	100	4800	513	10	31	-	-
19	4AHPN001.62	13	25	16000	4435	9	69	1	8
20	4AHPN001.62	14	25	16000	5190	11	79	2	14
21	4AHTA003.26	3	78	1000	393	1	33	-	-
22	4ALNT001.00	1	525	525	525	1	100	-	-
23	4ALOR008.64	71	100	8000	1023	30	42	-	-
24	4ALOR010.78	37	100	8000	1081	19	51	-	-
25	4ALOR014.33	24	100	8000	1063	11	46	-	-
26	4ALOR014.75	171	25	8000	826	61	35	2	1
27	4ALRO003.34	41	100	700	161	2	5	-	-
28	4AOWC002.35	16	10	6900	683	3	19	-	-
29	4AOWC002.35	18	10	6900	698	4	22	1	6
30	4AOWC005.36	46	25	8000	813	16	35	2	4
31	4APGG003.29	78	25	8000	826	24	31	4	5
32	4APGG008.87	13	25	2000	500	6	46	2	15
33	4APGG016.06	13	25	2400	693	5	38	2	15
34	4APGG030.62	58	40	8000	669	17	29	1	2
35	4APGG052.73	130	40	16000	1159	53	41	7	5
36	4APGG068.49	28	75	8000	703	7	23	1	4
37	4APGG074.87	23	75	8000	1201	7	30	2	9
38	4AROA059.12	163	10	16000	1036	40	25	2	1
39	4AROA067.91	84	20	16000	590	16	19	2	2
40	4AROA097.46	171	1	8000	494	33	19	3	2
41	4AROA108.09	37	1	5000	309	5	14	-	-
42	4AROA124.59	12	100	900	250	2	17	-	-
43	4AROA129.55	89	1	2000	208	9	10	-	-
44	4AROA145.34	35	100	600	114	1	3	-	-
45	4AROA153.59	34	100	3400	200	1	3	-	-
46	4ASCE000.26	61	100	4800	351	8	13	-	-

No.	Station	No of Samples Collected Between 1990-2005	Sample Value (cfu/100ml)			Exceedances of WQS			
						Inst. Max[1]		Geo. Mean[2]	
			Min	Max	Average	No.	%	No.	%
47	4ASDA000.67	16	30	7000	777	6	38	3	19
48	4ASDA007.24	17	50	4700	508	3	18	-	-
49	4ASDA009.77	128	128	128	128	51	40	3	2
50	4ASDA009.79	104	104	104	104	58	56	4	4
51	4ASEE003.16	47	100	8000	1772	22	47	-	-
52	4ASLA002.69	11	18	9200	1060	2	18	-	-
53	4ASNW000.60	69	1	9000	922	18	26	4	6
54	4ASNW010.08	6	25	7200	1339	1	17	-	-
55	4ASRN005.14	9	100	590	154	1	11	-	-
56	4ATCC003.71	6	25	800	203	1	17	-	-
57	4ATIP002.55	51	30	9200	996	14	27	-	-
58	4ATMA001.46	13	25	5200	605	3	23	1	8
59	4AWEL000.59	1	1500	1500	1500	1	100	-	-
60	4AWFC002.12	35	25	5400	400	4	11	-	-
61	4AWFC002.12	35	25	5400	400	4	11	-	-
62	4AXMC000.54	23	18	16000	1522	8	35	6	26

[1] Instantaneous maximum fecal coliform bacteria concentration of 400 cfu/100 ml
[2] Geometric mean fecal coliform bacteria concentration of 200 cfu/100 ml, calculated only when two or more samples are collected in a calendar month
Note: Rows highlighted in yellow are listing stations for the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River bacteria impairments.

Table 3-9: Summary of DEQ E. coli Bacteria Sampling Events that Exceeded the Water Quality Standards within the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River Watersheds.

No.	Station	No of Samples (2003-2005)	Sample Value (counts/100ml)			Exceedances of Water Quality Standards			
						Inst. Max[1]		Geo. Mean[2]	
			Min	Max	Average	No.	%	No.	%
1	4ABES001.21	12	25	1200	390	5	42	-	-
2	4ABHA002.47	24	25	950	154	4	17	1	4
3	4ABNN001.85	29	25	8000	658	14	48	5	17
4	4ABUB000.06	27	25	1200	304	12	44	2	7
5	4ABUB006.50	12	25	2000	448	3	25	-	-
6	4ACAR001.70	1	500	500	500	1	100	-	-
7	4ACBA000.22	11	25	1500	209	2	18	-	-
8	4ACNT001.32	12	25	2000	465	6	50	-	-
9	4ACNT012.10	6	25	320	121	3	50	-	-
10	4ACRE002.52	12	25	880	156	3	25	-	-
11	4ACUB002.21	12	25	2000	374	3	25	1	8
12	4ACUB005.46	12	25	2000	305	3	25	1	8
13	4ACUB010.96	20	6	8000	547	3	15	-	-
14	4ACUB017.46	30	25	2000	271	6	20	2	7
15	4ADFF004.90	11	25	380	118	2	18	-	-
16	4ADFF009.01	11	25	1700	290	5	45	-	-
17	4AECR003.02	1	600	600	600	1	100	-	-
18	4AECR016.66	1	380	380	380	1	100	-	-
19	4AFSF004.56	12	25	1900	325	4	33	-	-
20	4AGSE025.64	1	250	250	250	1	100	-	-
21	4AGSE025.64	3	25	250	158	1	33	-	-
22	4AGSE037.78	12	25	930	358	8	67	-	-
23	4AHPN001.62	14	75	2000	968	9	64	-	-
24	4AHTA000.77	23	25	400	78	2	9	-	-

No.	Station	No of Samples (2003-2005)	Sample Value (counts/100ml)			Exceedances of Water Quality Standards			
						Inst. Max[1]		Geo. Mean[2]	
			Min	Max	Average	No.	%	No.	%
25	4ALNT001.00	1	430	430	430	1	100	-	-
26	4ALOU001.16	12	25	1900	485	4	33	1	8
27	4ALUB000.12	12	25	500	192	4	33	-	-
28	4AOWC002.35	16	10	1600	234	4	25	-	-
29	4AOWC005.36	12	10	2000	475	5	42	-	-
30	4APGG003.29	23	50	930	252	6	26	-	-
31	4APGG008.87	13	25	1900	452	7	54	1	8
32	4APGG016.06	13	25	2000	552	8	62	-	-
33	4APGG030.62	17	25	930	293	8	47	4	24
34	4APGG052.73	21	20	2000	523	13	62	2	10
35	4APGG068.49	16	100	820	291	9	56	3	19
36	4APGG074.87	12	75	2000	426	5	42	-	-
37	4AROA059.12	26	6	8000	457	4	15	1	4
38	4AROA067.91	25	2	8000	450	5	20	3	12
39	4AROA097.46	27	1	800	107	3	11	2	7
40	4AROA108.09	15	4	380	52	5	33	-	-
41	4AROA129.55	27	6	1000	97	2	7	1	4
42	4AROA140.66	5	25	875	195	2	40	-	-
43	4AROA145.34	5	25	500	190	2	40	-	-
44	4AROA153.59	5	25	450	185	2	40	-	-
45	4AROC001.00	12	25	530	169	3	25	-	-
46	4ASDA000.67	16	84	1000	383	9	56	3	19
47	4ASDA007.24	6	25	1000	280	2	33	-	-
48	4ASDA009.79	12	10	2000	427	5	42	-	-
49	4ASLA001.52	12	25	600	133	1	8	-	-
50	4ASLA001.52	14	25	600	123	1	7	-	-
51	4ASNW000.60	22	25	1600	321	8	36	2	9
52	4ASNW010.08	6	100	2000	458	1	17	-	-
53	4ASSC002.98	12	25	800	302	6	50	-	-
54	4ATCC003.71	6	25	680	184	3	50	-	-
55	4ATIP002.55	14	25	8000	994	5	36	1	7
56	4ATIP008.76	12	75	2000	669	3	25	-	-
57	4ATIP013.21	12	25	2000	510	4	33	-	-
58	4ATMA001.46	13	25	800	233	3	23	-	-
59	4ATWT000.32	14	25	800	119	1	7	-	-
60	4ATYS001.25	1	420	420	420	1	100	-	-
61	4AWFC002.12	13	25	800	170	1	8	-	-
62	4AWLF000.09	3	25	620	288	1	33	-	-
63	4AWPP002.53	28	25	2000	198	3	11	1	4
64	4AXMC000.54	11	25	1200	273	2	18	-	-

[1] Instantaneous maximum E. coli bacteria concentration of 235/100 ml

[2] Geometric mean fecal E. coli bacteria concentration of 126/100 ml, of water for two or more samples taken during any calendar month

Note: Rows highlighted in yellow are listing stations for the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River bacteria impairments.

3.4.1 Bacteria Source Tracking

As part of the TMDL development, Bacteria Source Tracking (BST) sampling was conducted at 8 locations throughout the watershed. The objective of the BST study was to identify the sources of fecal coliform in the listed segments of Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River. After identifying these sources, this information was used in the model set-up, and in the distribution of fecal coliform loadings among the various sources.

There are various methodologies used to perform BST, which fall into three major categories: molecular, biochemical and chemical. Molecular (genotype) methods are referred to as “DNA fingerprinting,” and are based on the unique genetic makeup of different strains, or subspecies, of fecal coliform bacteria. Biochemical (phenotype) methods are based on detecting biochemical substances produced by bacteria. The type and quantity of these substances are measured to identify the bacteria source. Chemical methods are based on testing for chemical compounds that are associated with human wastewaters, and are restricted to determining if sources of pollution are human or non-human.

For the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDLs, the Antibiotic Resistance Analysis (ARA) method of BST was used. ARA has been the most widely used and published BST method to date and has been employed in Virginia, Florida, Kansas, Oregon, South Carolina, Tennessee, and Texas. Advantages of ARA include low cost per sample, and fast turnaround times for analyzing samples. The method can also be performed on large numbers of isolates; typically, 48 isolates per unknown source such as an in-stream water quality sample.

In the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed, BST was conducted monthly at 8 monitoring stations from July 2003 through June 2004. A total of 12 sampling events were collected at each station. The location of each BST station is presented in **Table 3-10**. **Figure 3-5** depicts the locations of the monitoring stations in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed.

Table 3-10: DEQ BST Stations Located in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watershed

Watershed Code	Station ID	Station Description	Stream Name	County
VAW-L02R	4ABNN001.85	At Route 608	Buffalo Creek	Charlotte
VAW-L02R	4ACUB010.96	Route 40 Bridge – Charlotte County	Cub Creek	Charlotte
VAC-L4OR	4AROA059.12	Route 360 Bridge, East of Clover	Staunton River	Charlotte
VAC-L38R	4AROA067.91	Route 746 Bridge (Watkins Bridge) Near Rand	Staunton River	Halifax
VAC-L30R	4AROA097.46	Brookneal Gage, Route 50	Staunton River	Campbell
VAC-L30R	AROA108.09	Route 761 Bridge – Main Channel of Staunton	Staunton River	Campbell
VAC-L19R	4AROA129.55	Route 29 Bridge, At Gage– Pittsylvania	Staunton River	Pittsylvania
VAC-L36R	4ATIP002.55	Route 619 Bridge	Turnip Creek	Charlotte

Four categories of fecal bacteria sources were considered: wildlife, human, livestock and pet. Monitoring results at the different BST stations for 12 sampling events are presented in **Table 3-11**. E. coli concentrations exceeded the instantaneous maximum E. coli bacteria criterion of 235 counts/100ml 20 times in the 96 samples collected at all 8 stations. In terms of percentages, the instantaneous E. coli standard was violated any where between 0 percent of the time at Staunton River Station 4AROA097.46 to 50 percent of the time at the station on Buffalo Creek (4ABNN001.85). The weighted averages, which account for concentration, number of isolates and flow, indicated that the E. coli from humans, wildlife, livestock and pet sources were present in all of the samples. **Figures 3-6** to **3-13** depict the BST distributions at all 8 stations within the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River Watershed.

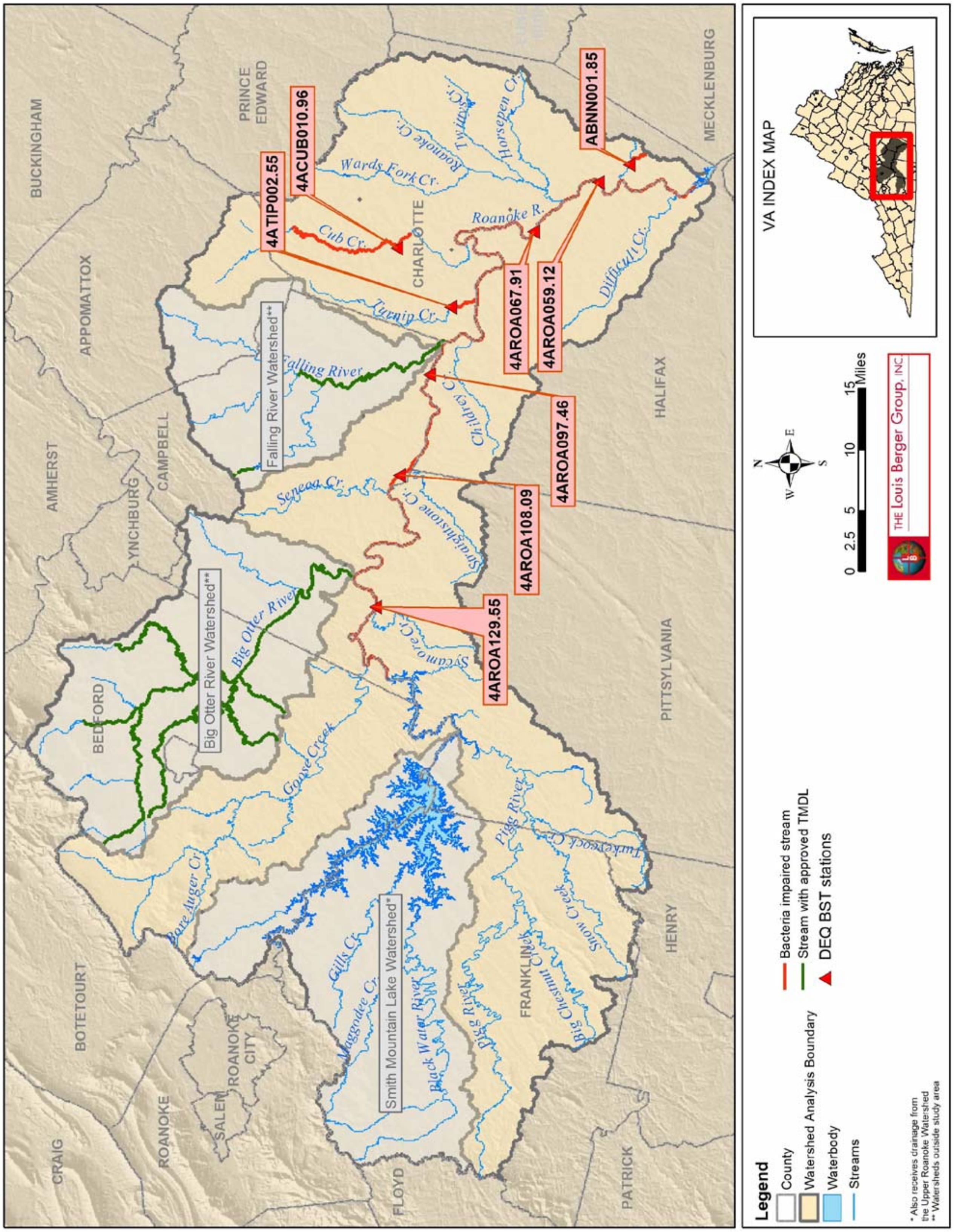


Figure 3-5: Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watershed Bacteria Source Tracking Sampling Stations

Table 3-11: Results of BST Analysis

VADEQ ID	Date	# of Isolates	*E. coli* (no./100 ml)	Wildlife	Human	Livestock	Pet
4ABNN001.85 6 of the 12 (50%) samples exceed 235 no./100ml	7/29/03	24	250	**25%**	**12%**	**55%**	8%
	8/19/03	24	730	**25%**	0%	**75%**	0%
	9/30/03	24	136	4%	4%	**50%**	**42%**
	10/28/03	24	400	**38%**	**12%**	**50%**	0%
	11/20/03	24	510	**33%**	0%	**59%**	8%
	12/30/03	24	138	**17%**	8%	4%	**71%**
	1/13/04	24	8000	**21%**	**25%**	**50%**	4%
	2/18/04	24	70	**54%**	**46%**	0%	0%
	3/23/04	24	72	**63%**	**25%**	**12%**	0%
	4/27/04	24	150	8%	**12%**	**47%**	**33%**
	5/18/04	7	30	0%	100%	0%	0%
	6/22/04	24	610	8%	**46%**	**21%**	**25%**
	Weighted Average			24%	16%	50%	10%
4ACUB010.96 3 of the 12 (25%) samples exceed 235 no./100ml	7/29/03	24	440	**38%**	**29%**	**33%**	0%
	8/19/03	24	210	0%	0%	**100%**	0%
	9/30/03	24	56	4%	8%	**84%**	4%
	10/28/03	24	1060	**29%**	**12%**	**59%**	0%
	11/20/03	24	8000	**29%**	**17%**	**42%**	**12%**
	12/30/03	18	38	**50%**	**17%**	0%	**33%**
	1/13/04	24	34	**55%**	**12%**	8%	**25%**
	2/18/04	4	6	25%	25%	0%	50%
	3/23/04	5	8	80%	20%	0%	0%
	4/27/04	24	110	**21%**	8%	**33%**	**38%**
	5/18/04	14	60	**36%**	**36%**	7%	**21%**
	6/22/04	10	90	**80%**	20%	0%	0%
	Weighted Average			29%	17%	43%	11%
4AROA059.12 2 of the 12 (17%) samples exceed 235 no./100ml	7/29/03	24	52	**42%**	0%	**12%**	**46%**
	8/19/03	24	44	4%	4%	**92%**	0%
	9/30/03	24	114	**17%**	0%	**71%**	**12%**
	10/28/03	24	360	**33%**	**12%**	**55%**	0%
	11/20/03	24	8000	4%	0%	**88%**	8%
	12/30/03	13	16	**38%**	**46%**	8%	8%
	1/13/04	24	24	**12%**	**17%**	**17%**	**54%**
	2/18/04	3	6	33%	0%	67%	0%
	3/23/04	4	6	50%	50%	0%	0%
	4/27/04	20	90	10%	**15%**	**40%**	**35%**
	5/18/04	12	60	0%	**67%**	**33%**	0%
	6/22/04	1	10	0%	100%	0%	0%
	Weighted Average			5%	1%	87%	8%
4AROA067.91 3 of the 12 (25%) samples exceed 235 no./100ml	7/29/03	16	30	12%	0%	**88%**	0%
	8/19/03	24	270	0%	0%	**100%**	0%
	9/30/03	24	132	**21%**	4%	**75%**	0%
	10/28/03	24	740	**46%**	**12%**	**42%**	0%
	11/20/03	24	8000	8%	0%	**84%**	8%
	12/30/03	18	24	11%	11%	**50%**	**28%**
	1/13/04	24	24	**25%**	8%	**17%**	**50%**
	2/18/04	6	12	66%	0%	17%	17%
	3/23/04	1	2	0%	100%	0%	0%
	4/27/04	24	140	**42%**	**25%**	**25%**	8%
	5/18/04	12	60	**25%**	**58%**	17%	0%
	6/22/04	2	20	100%	0%	0%	0%
	Weighted Average			10%	1%	82%	8%
4AROA097.46 0 of the 12 (0%) samples exceed 235 no./100ml	7/28/03	*NVI	10	*NVI	*NVI	*NVI	*NVI
	8/18/03	24	210	**54%**	**38%**	8%	0%
	9/29/03	24	122	8%	0%	**92%**	0%
	10/27/03	24	58	**71%**	8%	**21%**	0%

VADEQ ID	Date	# of Isolates	*E. coli* (no./100 ml)	Wildlife	Human	Livestock	Pet
	11/19/03	24	146	**38%**	**20%**	4%	**38%**
	12/29/03	11	18	**46%**	9%	**27%**	18%
	1/12/04	0	0	0%	0%	0%	0%
	2/17/04	8	16	38%	24%	38%	0%
	3/22/04	5	8	40%	60%	0%	0%
	4/26/04	4	30	25%	75%	0%	0%
	5/17/04	6	80	67%	0%	0%	33%
	6/21/04	0	0	0%	0%	0%	0%
	Weighted Average			43%	23%	21%	14%
4AROA108.09 1 of the 12 (8%) samples exceed 235 no./100ml	7/28/03	16	28	12%	0%	12%	**76%**
	8/18/03	24	660	**29%**	0%	**25%**	**46%**
	9/29/03	24	70	8%	0%	**88%**	4%
	10/27/03	24	28	**38%**	4%	**33%**	**25%**
	11/19/03	24	110	**34%**	**12%**	**25%**	**29%**
	12/29/03	3	4	34%	0%	33%	33%
	1/12/04	8	10	75%	25%	0%	0%
	2/17/04	19	28	**26%**	**48%**	**26%**	0%
	3/22/04	*NVI	4	*NVI	*NVI	*NVI	*NVI
	4/26/04	5	20	60%	40%	0%	0%
	5/17/04	2	20	50%	0%	0%	50%
	6/21/04	1	10	0%	100%	0%	0%
	Weighted Average			49%	8%	44	0
4AROA129.55 1 of the 12 (8%) samples exceed 235 no./100ml	7/28/03	4	8	0	0	100	0
	8/18/03	24	1200	17	0	66	17
	9/29/03	24	56	8	0	88	4
	10/27/03	24	118	0	4	96	0
	11/19/03	24	92	**54%**	**29%**	17%	0%
	12/29/03	7	12	86%	0%	14%	0%
	1/12/04	8	16	50%	38%	0%	12%
	2/17/04	15	24	**20%**	**33%**	20%	**27%**
	3/22/04	3	6	33%	0%	0%	67%
	4/26/04	2	40	0%	50%	50%	0%
	5/17/04	2	80	50%	0%	50%	0%
	6/21/04	2	20	0%	100%	0%	0%
	Weighted Average			16	0	68	16
4ATIP002.55 4 of the 12 (33%) samples exceed 235 cfu/100ml	7/28/03	24	200	**33%**	**17%**	8%	**42%**
	8/18/03	24	74	**63%**	8%	**12%**	**17%**
	9/29/03	24	350	**12%**	0%	**88%**	0%
	10/27/03	24	400	0%	0%	**100%**	0%
	11/19/03	24	8000	0%	4%	**79%**	**17%**
	12/29/03	24	36	**17%**	4%	**46%**	**33%**
	1/12/04	22	34	**63%**	5%	**23%**	9%
	2/17/04	*NVI	40	*NVI	*NVI	*NVI	*NVI
	3/22/04	24	50	**29%**	0%	**46%**	**25%**
	4/26/04	24	580	**29%**	**50%**	**21%**	0%
	5/17/04	24	180	8%	**42%**	**29%**	**21%**
	6/21/04	20	220	**75%**	**15%**	10%	0%
	Weighted Average			21	24	52	3

BOLD type indicates a statistically significant value.

*NVI - No Viable Isolates

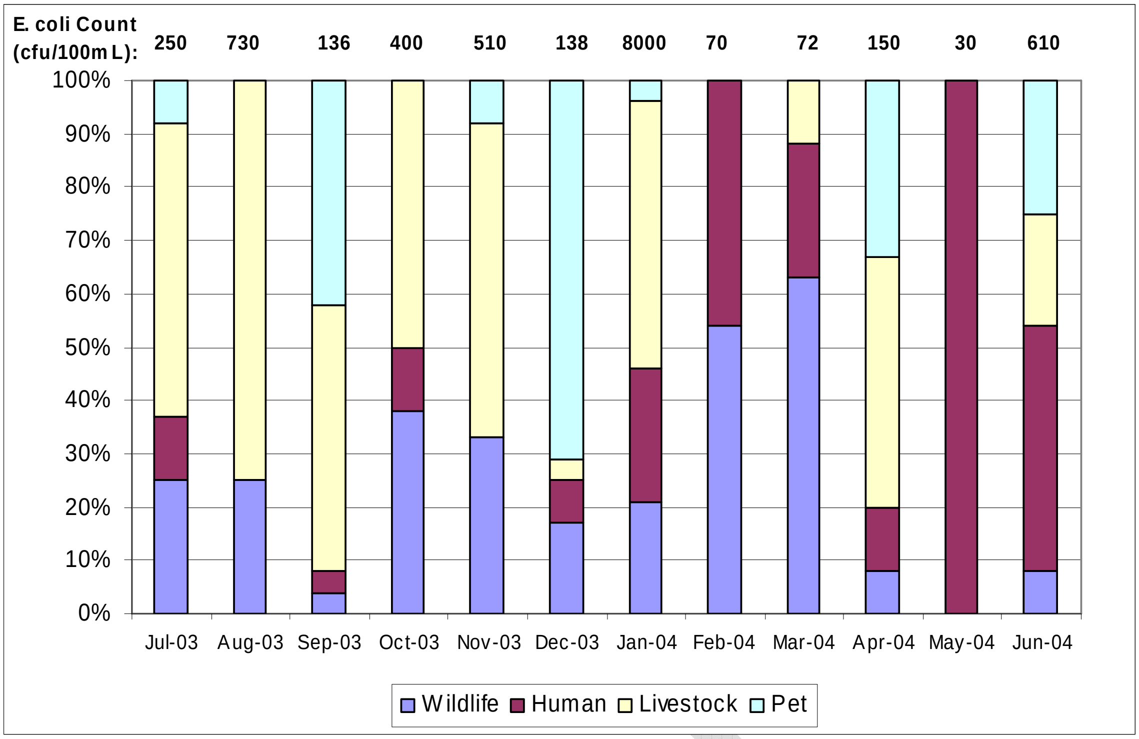


Figure 3-6: BST Data at Station 4ABNN001.85

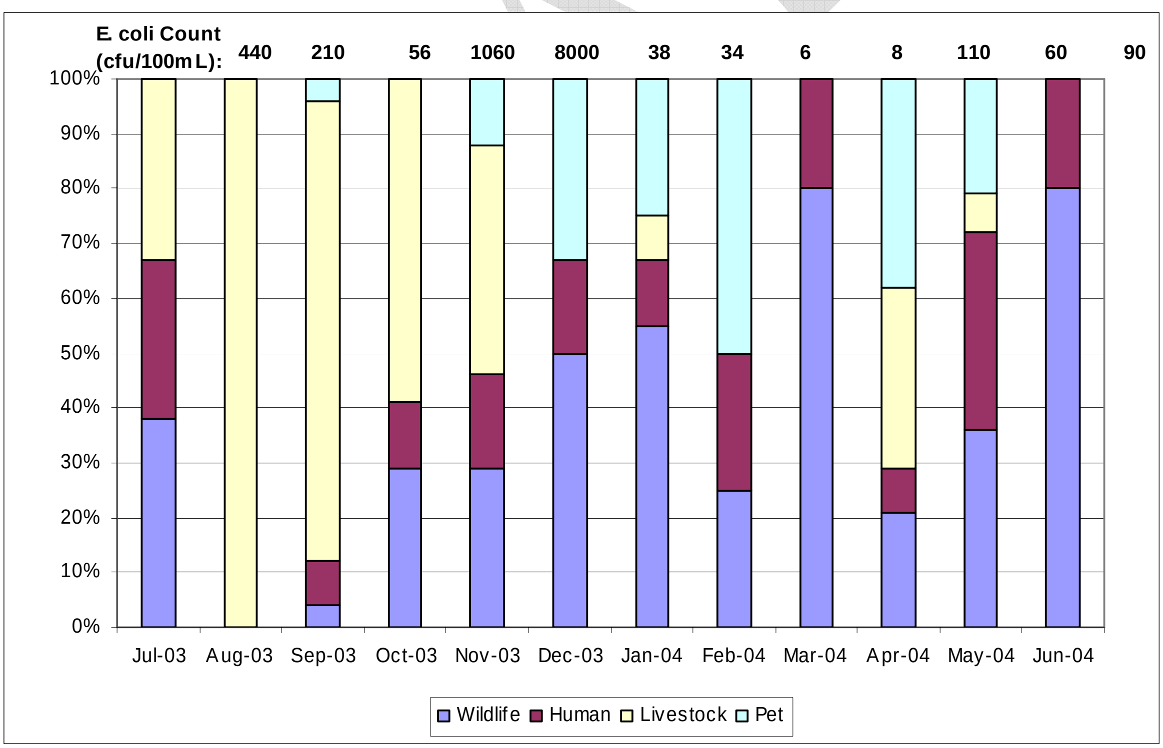


Figure 3-7: BST Data at Station 4ACUB010.96

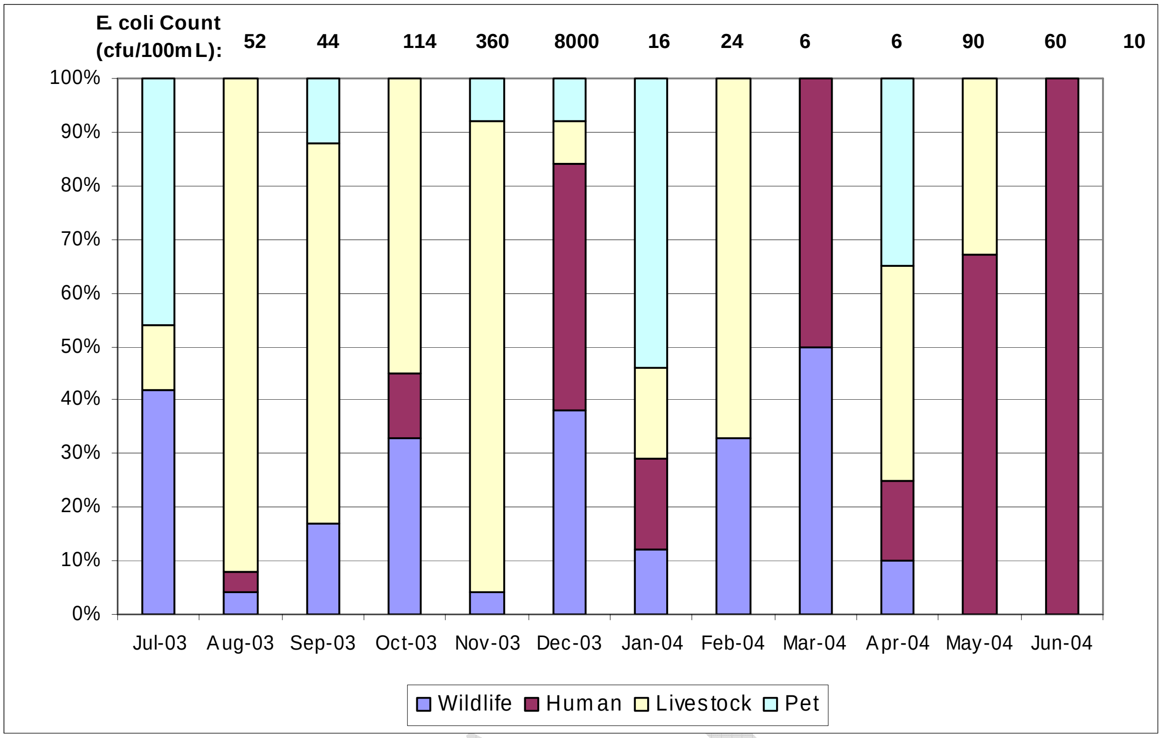


Figure 3-8: BST Data at Station 4AROA059.12

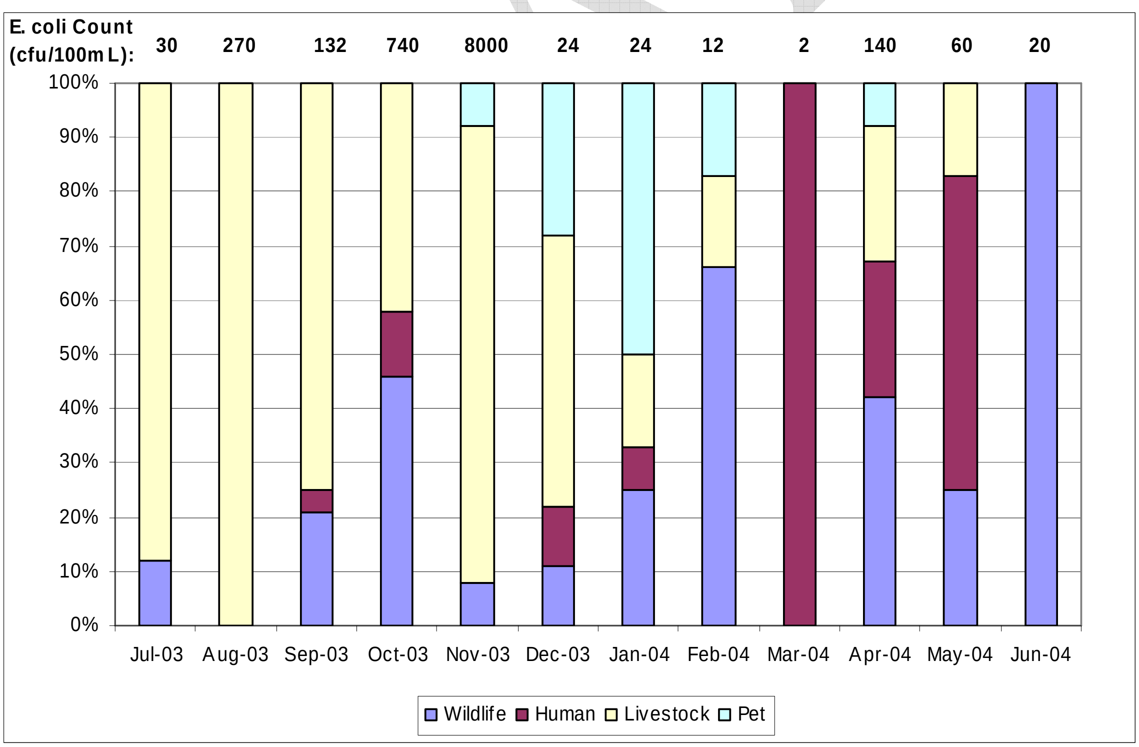


Figure 3-9: BST Data as Station 4AROA067.91

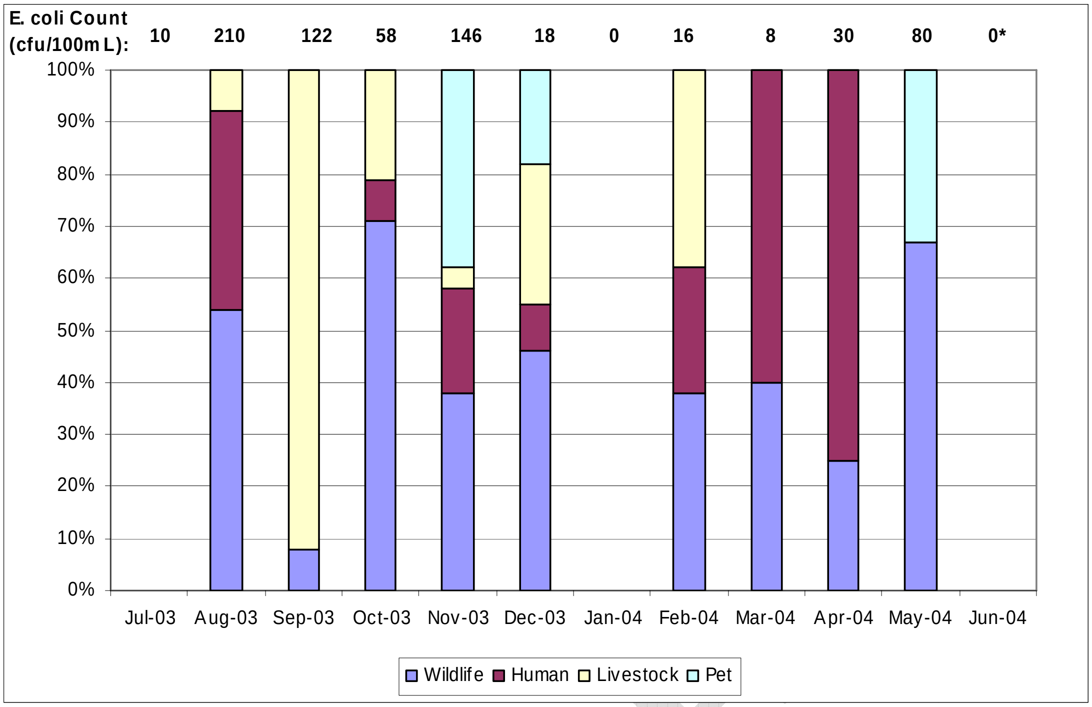


Figure 3-10: BST data at Station 4AROA097.46

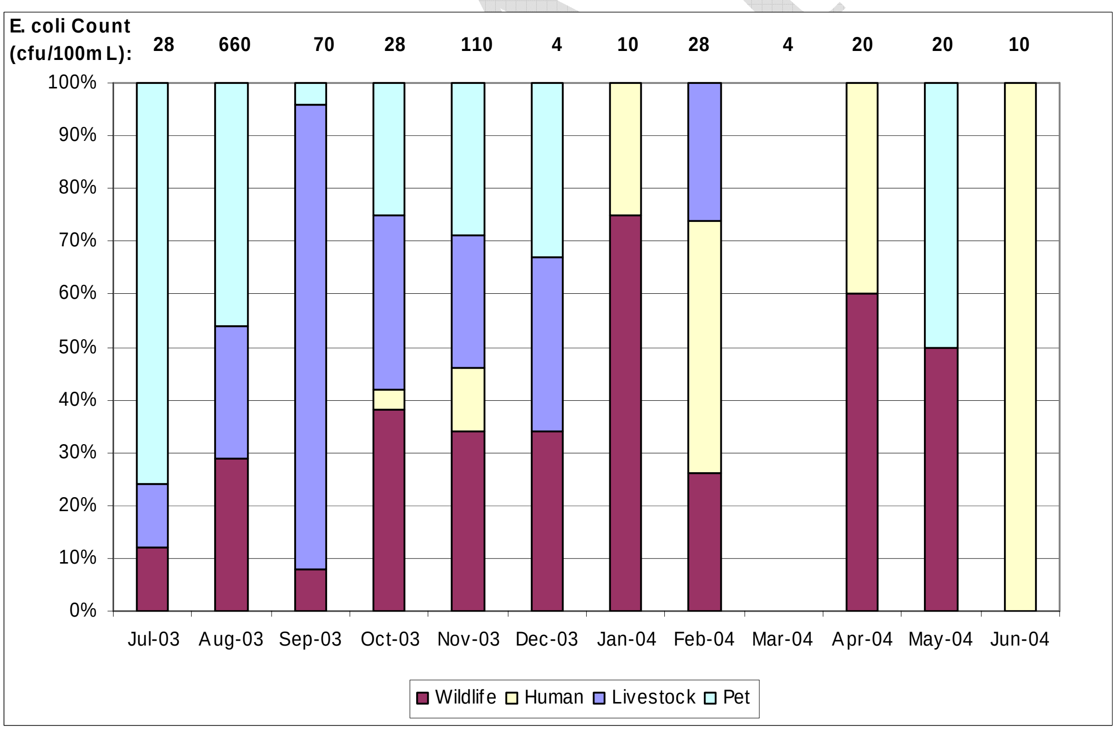


Figure 3-11: BST Data at Station 4AROA108.09

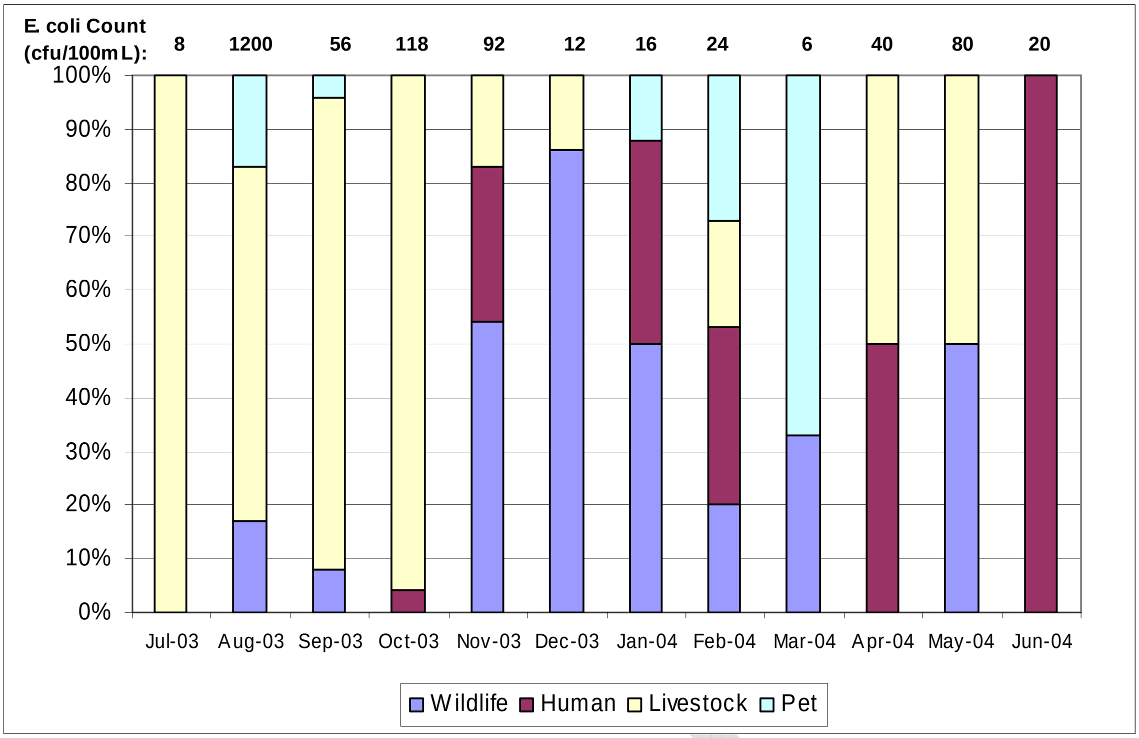


Figure 3-12: BST Data at Station 4AROA129.55

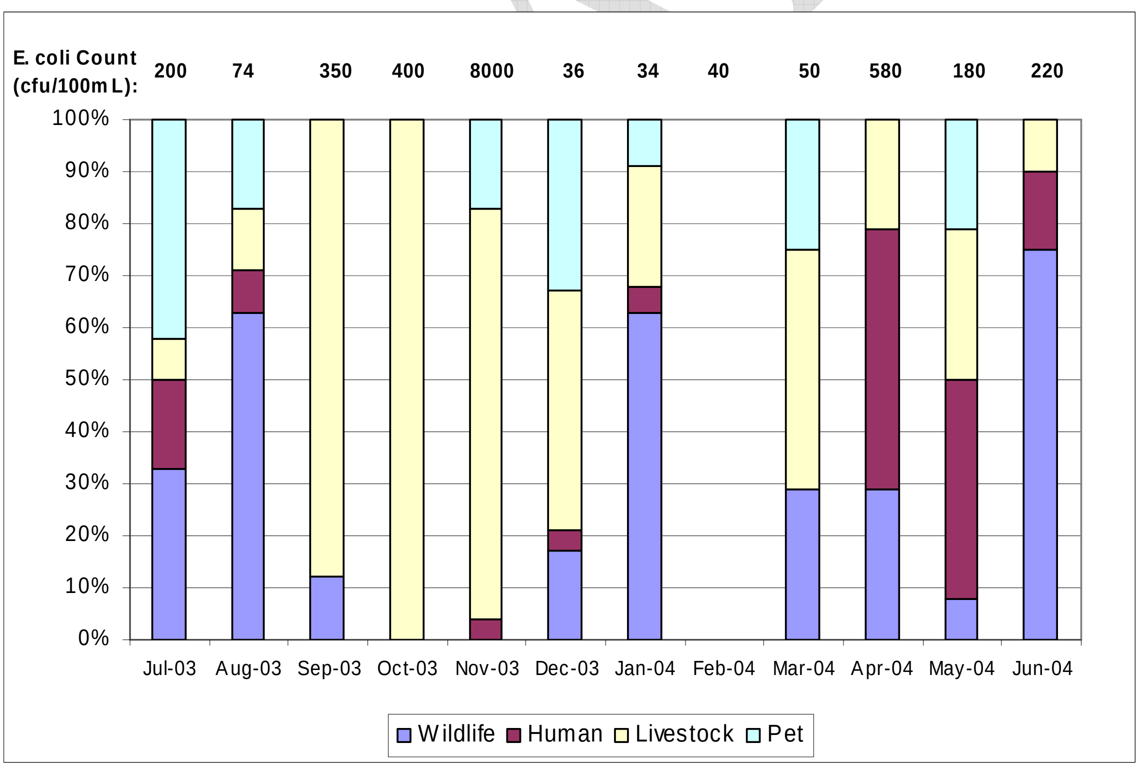


Figure 3-13: BST Data at Station 4ATIP002.55

3.5 Fecal Coliform Source Assessment

This section focuses on characterizing the sources that potentially contribute to the fecal coliform loading in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. These sources include permitted facilities, sanitary sewer systems and septic systems, livestock, land application of manure and biosolids, wildlife, and pets. Chapter 4 includes a detailed presentation of how these sources are incorporated and represented in the model.

3.5.1 Permitted Facilities

Data obtained from the DEQ's South Central Regional Office indicate that there are 45 individually permitted facilities located in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed, not including the Falling River and Big Otter Watersheds. The permit number, design flow, and status for each permits are presented in **Table 3-12**. The locations of the individual permits are presented in **Figure 3-14** (latitudes and longitudes were not consistently available for the general permits and they could not be mapped). Only municipal facilities are potentially significant sources of fecal coliform, but the flow from all permitted dischargers will be considered in the hydrology calibration.

Table 3-12: Active Permitted Discharges in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watershed

Permit Number	Facility Name	Facility Type	Design Flow (gpd)[1]	Receiving Waterbody	Status
VA0020451	Altavista Town – Wastewater Treatment Plant	Municipal	3600000	Staunton River	Active
VA0087106	American Electric Power – Leesville Hydro Plant	Industrial	1465000	Staunton River	Active
VA0087238	Bedford County – PSA New Montvale Elementary School	Municipal	20000	Goose Creek, South Fork	Active
VA0063738	Bedford County – Staunton River High School	Municipal	25600	Shoulder Run, UT	Active
VA0020869	Bedford County – Thaxton Elementary School	Municipal	3500	Wolf Creek, UT	Active
VA0089052	Blue Ridge Wood Preserving Inc	Industrial	0	Hunting Creek, UT	Active
VA0054577	BP Products North America Inc	Industrial	0	Goose Creek, South Fork	Active

Permit Number	Facility Name	Facility Type	Design Flow (gpd)[1]	Receiving Waterbody	Status
VA0022241	Brookneal Town – Staunton River Lagoon	Municipal	78000	Staunton River	Active
VA0001678	Burlington Industries LCC Hurt Plant	Industrial	3275000	Staunton River	Active
VA0060909	Camp Virginia Jaycees STP	Municipal	15000	Day Creek, UT	Active
VA0029319	Charlotte County School Bacon District Elementary	Municipal	6000	Little Horsepen Creek, UT	Active
VA0063118	Charlotte County School Jeffress Elementary	Municipal	4000	UT Sandy Creek	Active
VA0029335	Charlotte County School Phenix Elementary	Municipal	6000	UT Terrys Creek	Active
VA0073733	Clover WWTP	Municipal	35000	Clover Creek	Active
VA0051721	Colonial Pipeline Co	Industrial	17000	Goose Creek, South Fork	Active
VA0051934	Colonial Pipeline Hancock	Industrial	1500	Turnip Creek/UT	Active
VA0001538	Dan River Inc – Brookneal	Industrial	1326000	Staunton River	Active
VA0083402	Dominion – Altavista PS	Industrial	87200	Staunton River	Active
VA0083399	Dominion – Pittsylvania PS	Industrial	192000	Staunton River	Active
VA0084433	Drakes Branch WWTP	Municipal	80000	Twitty's Creek	Active
VA0022748	Halifax Co School Clays Mill Elementary	Municipal	7200	Mill Branch, UT	Active
VA0024058	Keysville WWTP	Municipal	250000	Ash Camp Creek	Active
VA0023515	Moneta Adult Detention Facility	Municipal	21000	Mattox Creek, UT	Active
VA0001490	Motiva Enterprises LLC – Montvale	Industrial	65000	Goose Creek, South Fork	Active
VA0083097	Old Dominion Electric Coop Clover	Industrial	1735000	Staunton River	Active
VA0026051	Trans Montaigne Terminaling Inc – Atlantic	Industrial	569000	Goose Creek, South Fork	Active
VA0051446	TransMontaigne Terminaling Inc – Piedmont	Industrial	467000	Goose Creek, South Fork, UT	Active
VA0050822	Westpoint Stevens Inc Drakes Branch	Industrial	80700	Twitty's Creek	History
VA0074870	Woodhaven Nursing Home - Montvale	Municipal	4800	Goose Creek, South Fork, UT	Active
VAG404017	Domestic Sewage Discharge	Residence	1000	Hazelnut Branch UT	Active
VAG404021	Domestic Sewage Discharge	Residence	450	Tanyard Branch UT	Active
VAG404081	Domestic Sewage Discharge	Residence	450	Berles Creek UT	Active
VAG404106	Domestic Sewage Discharge	Residence	450	Hazelnut Branch UT	Active
VAG404143	Domestic Sewage Discharge	Residence	600	Horsepen Creek	Active

[1]: Gallons per day

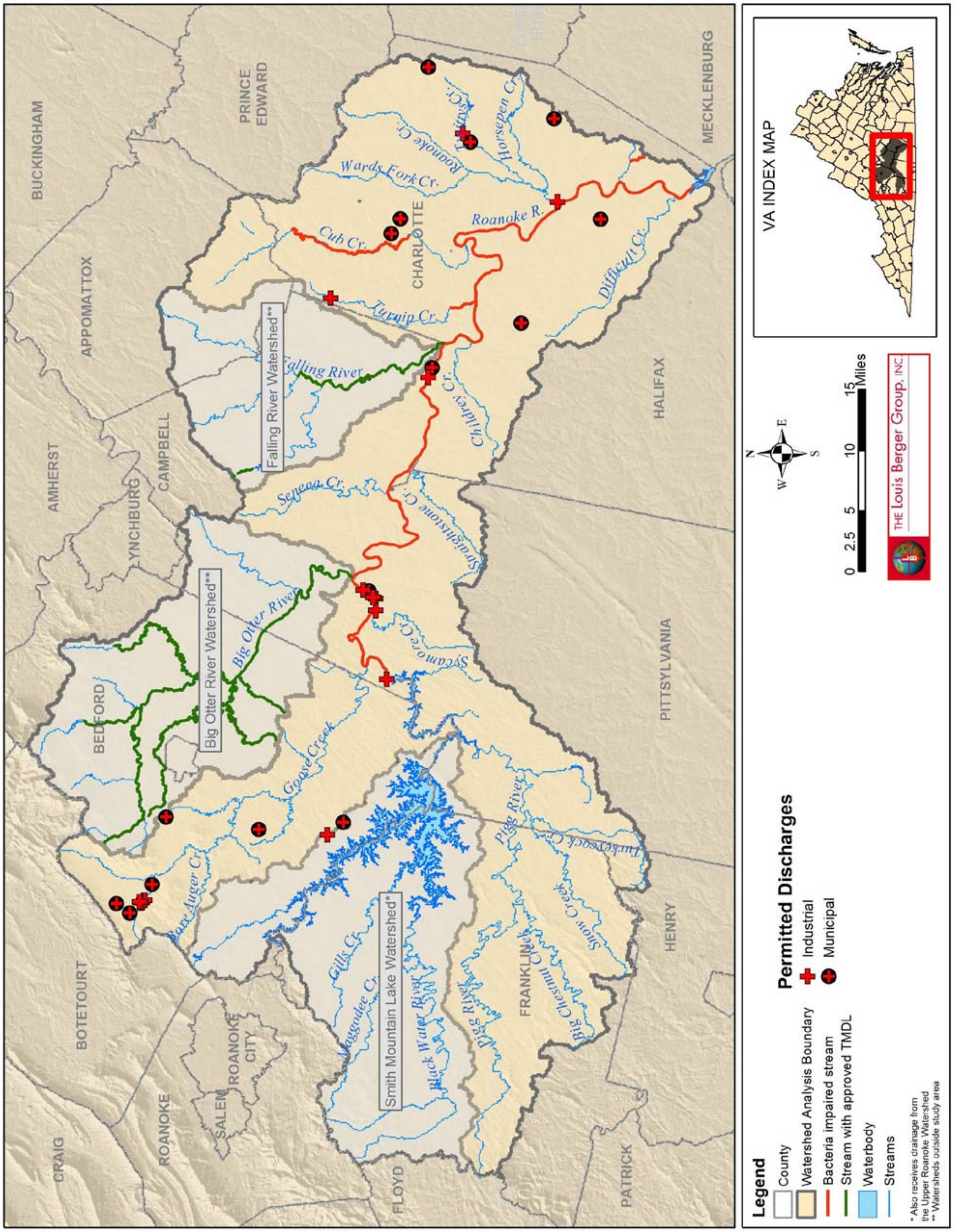


Figure 3-14: Location of Permitted Facilities in the Cub Creek, Turnip Creek, Buffalo Creek (UT) and Staunton River Watersheds

The available flow data for the permitted facilities was retrieved and analyzed. Average flows for the permitted facilities were used in the HSPF model set-up and calibration. Fecal coliform data were available only for the Altavista Town WWTP and Burlington Industries LCC Hurt Plant and were not available for other permitted facilities. **Table 3-13** shows the design flow, average flow, permitted bacteria concentration, and average bacteria concentrations recorded for the two permitted facilities. Available discharge monitoring report data is shown in Appendix A. Waste treatment plants use chlorine for disinfection, and measure total contact chlorine as an indication of fecal coliform levels. The available data indicate that adequate disinfection was achieved at the plants, and that these facilities were not a large source of fecal coliform loading. For TMDL development, a conservative approach was taken by assuming a concentration of 3 cfu/100 ml was present in the plant effluent. This concentration was used in HSPF model calibration.

Table 3-13: Inventory and Characterization of Facilities within the Cub Creek, Turnip Creek, Buffalo Creek (UT) and Staunton River Watersheds

Permit Number	Facility Name	Facility Type	Design Flow (gpd)[1]	Average Flow (gpd)	Average Bacteria Conc. (cfu/100ml)
VA0020451	Altavista Town – Wastewater Treatment Plant	Municipal	3,600,000	3.48	2.34
VA0001678	Burlington Industries LCC Hurt Plant	Industrial	3,275,000	2.62	8.10

(1) gallons per day

3.5.2 Extent of Sanitary Sewer Network

Houses can be connected to a public sanitary sewer, a septic tank, or the sewage can be disposed by other means. Estimates of the total number of households connected to the sewer system are presented in the next section.

3.5.2.1 Septic Systems

There are no data available for the total number of septic systems in the watershed. Estimates of the total number of housing units located in the watershed and the identification of whether these housing units are connected to a public sewer or on septic systems were based on the following data sources:

- U.S. Census Bureau data

- USGS 7.5 minute quadrangle maps

The U.S. Census Bureau 2000 data and USGS quad maps were reviewed for Appomattox, Bedford, Campbell, Charlotte, Franklin, Halifax, Henry, and Pittsylvania counties to establish the population growth rates in the counties and to validate the housing units calculation. A summary of the census data for the Cub Creek, Turnip Creek, Buffalo Creek and Staunton River Watershed, is presented in **Table 3-14**.

Table 3-14: 2000 U.S. Census Data Summary for the Cub Creek, Turnip Creek, Buffalo Creek and Staunton River Watersheds

Watershed	County	Population	# Households	# Housing Units
Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watersheds	**Appomattox**	1,507	575	637
	Bedford	15,190	6,064	6,877
	Campbell	12,042	4,905	5,369
	Charlotte	10,382	4,110	4,761
	Franklin	21,824	8,605	9,556
	Halifax	6,940	2,759	3,185
	Henry	164	63	69
	Pittsylvania	10,756	4,414	5,147
Falling River Watershed[1]	**Appomattox and Campbell**	15,021	6,008	7,703
Big Otter River Watershed[2]	**Bedford and Campbell**	39,285	15,713	–

Source: U.S. Census Data, USGS Quad Maps
[1]Falling River estimates based on TMDL Report (2004)
[2]Big Otter River estimates based on TMDL Report (2001)

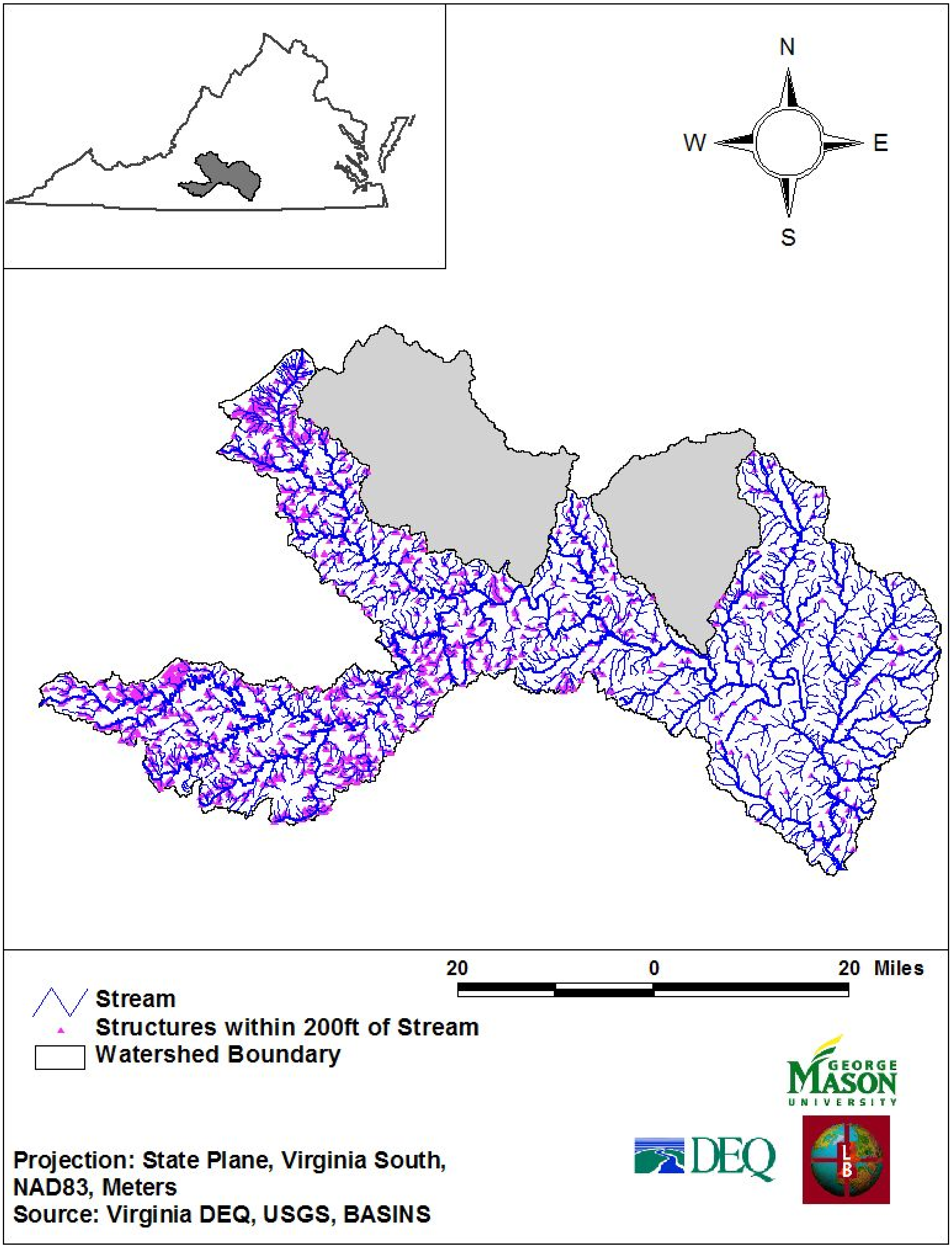
The 1990 U.S. Census Report presents the percent of houses on each sewage disposal type as shown in **Table 3-15**. The 1990 U.S. Census Report category “Other Means” included the houses that dispose of sewage in other ways than by public septic system. The houses included in this category are assumed disposing of sewage directly to the water via straight pipes if located within 200 feet of the stream **(Figure 3-15).**

Table 3-15: Sewage Disposal Distribution within Each County on Public Sewers, Septic Systems, and Other Means

County	% Public Sewer	% Septic Tank	% Other Means
Appomattox	12.66%	84.06%	3.28%
Bedford	6.75%	90.17%	3.09%
Campbell	18.78%	78.18%	3.04%
Charlotte	9.28%	80.65%	10.07%
Franklin	15.04%	81.40%	3.55%
Halifax	13.78%	76.68%	9.54%
Henry	33.82%	62.85%	3.33%
Pittsylvania	8.42%	85.60%	5.98%

Source: U.S. Census Data

Figure 3-15: USGS Structures within 200ft of Stream in the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River Watersheds



3.5.2.2 Failed Septic Systems

In order to determine the amount of fecal coliform contributed by human sources, the failure rates of septic systems must be estimated. Septic system failures are generally attributed to the age of a system. For this TMDL model, the failure rate was assumed to be 3 percent of the total septic systems in the watershed (estimated at 26,039). In order to determine the load of bacteria from these sources, it was assumed that the septic system design flow is 75 gallons per person per day and that each septic system on average supports 2.51 people. In addition, it was estimated that typical fecal coliform concentrations from a failed septic system is 10,000 cfu/100mL and from a straight pipe is 1,040,000 cfu/100 mL (Tinker Creek TMDL Report, 2004). **Table 3-16** shows the estimates of the population on septic systems and straight pipes, the amount of failing systems, and the flow and fecal coliform load produced daily within the Cub Creek, Turnip Creek, Buffalo Creek (UT) and Staunton River Watershed.

Table 3-16: Estimates of the Number of Septic Systems and Straight Pipes in the Cub Creek, Turnip Creek, Buffalo Creek (UT) and Staunton River Watershed

Category	Total # of People on System	# People per Household	# Failing Septics or Pipes	People Served	Flow (gal/day)	Daily Load (#/day)
Septic Systems	65,244	2.51	781	1,957	146,798	5.56E+10
Straight Pipes	290	2.51	116	290	21,740	8.56E+11

3.5.3 Livestock

An inventory of the livestock residing in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed was conducted using data and information provided by the Department of Conservation and Recreation (DCR), U.S. agricultural census data (2002), extension offices in Halifax, Pittsylvania, and Charlotte Counties, the VA Equine Report (2001) and field surveys. **Table 3-17** summarizes the livestock inventory in the watershed.

Table 3-17: Turnip Creek, Buffalo Creek (UT), and Staunton River Watershed Livestock Inventory.

Livestock Type	Number of Animals
Beef Cows	34,418
Dairy Cows	9,917
Hogs & Pigs	32,911
Sheep & Lambs	720
Horses & Ponies	3,801
Chicken/Layers	48,000

The livestock inventory was used to determine the fecal coliform loading by livestock in the watershed. **Table 3-18** shows the average fecal coliform production per animal per day contributed by each type of livestock.

Table 3-18: Daily Fecal Coliform Production of Livestock

Livestock Type	Daily Fecal Coliform Production (millions of cfu/day)	Reference
Cow	5,400	Metcalf and Eddy, 1991
Cow (Beef)	100,000	ASAE, 1998
Cow (Dairy)	100,000	ASAE, 1998
Pig	8,900	Metcalf and Eddy, 1991
	11,000	ASAE, 1998
Sheep	18,000	Metcalf and Eddy, 1991
	12,000	ASAE, 1998
Chicken	240	Metcalf and Eddy, 1991
	140	ASAE, 1998
Horse	420	ASAE, 1998
Source: USEPA Protocol for Developing Pathogen TMDLs, 2001		

The impact of fecal coliform loading from livestock is dependent upon whether loadings are directly deposited into the stream, or indirectly delivered to the stream via surface runoff. For this TMDL, fecal coliform deposited while livestock were in confinement or grazing was considered indirect deposit, and fecal coliform deposited when livestock directly defecate into the stream was considered direct deposit. The distribution of daily fecal coliform loading between direct and indirect deposits was based on livestock daily schedules.

For the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDL, the initial estimates of the beef cattle daily schedule were based on the Dodd Creek TMDL. The amount of time beef cattle spend in the pasture and stream was also presented during the public meetings where stakeholders provided comments. The monthly schedule was adjusted to reflect the conditions in the watershed.

The daily schedule for beef cattle that was accepted by the stakeholders is presented in **Table 3-19.** The daily schedule for dairy cows that was accepted by the stakeholders is presented in **Table 3-20**. The time beef cattle and dairy cows spend in the pasture or loafing was used to determine the fecal coliform load deposited indirectly. The directly deposited fecal coliform load from livestock was based on the amount of time they spend in the stream.

Table 3-19: Daily Schedule for Beef Cattle

	Time Spent in		
	Pasture	Stream	Loafing Lot
Month	(Hour)	(Hour)	(Hour)
January	23.50	0.50	0
February	23.50	0.50	0
March	23.25	0.75	0
April	23.00	1.00	0
May	23.00	1.00	0
June	22.75	1.25	0
July	22.75	1.25	0
August	22.75	1.25	0
September	23.00	1.00	0
October	23.25	0.75	0
November	23.25	0.75	0
December	23.50	0.50	0

Source: Dodd Creek TMDL Report, DCR 2002.

Table 3-20: Daily Schedule for Dairy Cows

Month	Time Spent in		
	Pasture (Hour)	Stream (Hour)	Loafing Lot (Hour)
January	7.45	0.25	16.30
February	7.45	0.25	16.30
March	8.10	0.50	15.40
April	9.35	0.75	13.90
May	10.05	0.75	13.20
June	10.30	1.00	12.70
July	10.80	1.00	12.20
August	10.80	1.00	12.20
September	11.05	0.75	12.20
October	11.00	0.50	12.50
November	10.30	0.50	13.20
December	9.15	0.25	14.60

Source: Dodd Creek TMDL Report, DCR 2002.

3.5.4 Land Application of Manure

Land application of the manure that cattle produce while in confinement is a typical agricultural practice. Both diary operations and beef cattle are present in the watershed. Because there are no large recorded feedlots, or a significant number of manure storage facilities present in the watershed, the manure produced by confined livestock was directly applied on the pasturelands, and was treated as an indirect source in the development of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDL.

3.5.4.1 Poultry Litter Transfer

Poultry litter is used as a soil amendment and has been recorded as being applied within the Staunton River, Buffalo Creek, Cub Creek, and Turnip Creek Watershed. VADEQ maintains records of poultry litter transfers and these records indicate that transfers of poultry litter within the study area occurred closest to the Buffalo Creek and Goose Creek watersheds (**Table 3-21**).

Table 3-21: Transfer of poultry litter within the Buffalo Creek and Goose Creek Watersheds

Nearest Waterbody to Application Area	Transfer of poultry Litter 2004 (tons)
Buffalo Creek	140
Goose Creek	1,120

3.5.5 Land Application of Biosolids

Non-point human sources of fecal coliform can be associated with the spreading of biosolids. Discussions with Virginia DOH indicated that there has been some biosolids land application in Appomattox, Bedford, Charlotte, Franklin, Halifax, Henry and Pittsylvania Counties within the TMDL study area. Recorded biosolids application conducted in 2003 and 2004 is presented in **Table 3-22**.

Table 3-22: Biosolids Application (dry ton/year) in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Watersheds

Year	Biosolids Application by County (dry tons/year)							
	Appomattox	Bedford	Campbell	Charlotte	Franklin	Halifax	Henry	Pittsylvania
2003	8,367	4,505	-	8,210	1,395	760	-	1,963
2004	6,964	6,220	-	9,201	4,851	0	-	3,239
Source: Virginia Department of Health (VDH)								

3.5.6 Existing Best Management Practices

Within the Cub Creek, Turnip Creek, Buffalo Creek (UT) and Staunton River Watersheds, Best Management Practices (BMPs) have been implemented in order to reduce the impacts of livestock within the watershed. **Table 3-23** shows the number of BMPS recorded in Halifax County within the watershed (Halifax Extension Office).

Table 3-23: Best Management Practices (BMPs) Recorded in Halifax County

Type of BMP	Number Recorded in Halifax County within the Watershed
BMP Practice (SL1/SL11/SL6/WP3)[1]	16
CREP/CRP Tree and Grass Implementation[2]	24
Watering Facilities	30
Total	**70**
[1] SL1- Permanent Vegetative Cover Establishment, SL6-Grazing Land Protection, SL11-Permanent Vegetative Cover on Critical Areas, WP3- Direct and Indirect Costs	
[2] Conservation Reserve Enhancement Program (CREP) Conservation Reserve Program (CRP)	

3.5.7 Wildlife

Similar to livestock contributions, wildlife contributions of fecal coliform can be both indirect and direct. Indirect sources are those that are carried to the stream from the surrounding land via rain and runoff events, whereas direct sources are those that are directly deposited into the stream.

The wildlife inventory for this TMDL was developed based on a number of information and data sources, including: (1) habitat availability, (2) Department of Game and Inland Fisheries (DGIF) harvest data and population estimates, and (3) stakeholder comments and observations.

A wildlife inventory was conducted based on habitat availability within the watershed for all animals except for geese. Since typical geese population density estimates include only migratory populations and do not include resident geese populations, the number of geese in the watershed was based on stakeholder communication (e-mail communication by S. Miles, dated October 3, 2005). The number of all other types of wildlife in the watershed was estimated by combining typical wildlife densities with available stream wildlife habitat. Typical wildlife densities are presented in **Table 3-24**.

Table 3-24: Wildlife Densities

Wildlife type	Population Density	Habitat Requirements
Deer	0.047 animals/acre	Entire watershed
Raccoon	0.07 animals/acre	Within 600 feet of streams and ponds
Muskrat	2.75 animals/acre	Within 66 feet of streams and ponds
Beaver	4.8 animals/mile of stream	
Goose*	0.004 animals/acre	Entire Watershed
Mallard	0.002 animals/acre	Entire Watershed
Wood Duck	0.0018 animals/acre	Within 66 feet of streams and ponds
Wild Turkey	0.01 animals/acre	Entire watershed excluding farmsteads and urban land uses

Source: Map Tech, Inc., 2001.
* Densities for migratory populations only

The wildlife inventory presented in **Table 3-25** was then confirmed with DGIF and DCR, and was presented to stakeholders and local residents for approval.

Table 3-25: Wildlife Inventory

Wildlife Type	Number of Animals
Deer	50,754
Raccoon	26,846
Muskrat	116,013
Beaver	12,656
Goose*	3,000
Mallard	84
Wood Duck	76
Wild Turkey	10,710

*Total number reflects resident geese population

The wildlife inventory was used to determine the fecal coliform loading by wildlife within the watershed. **Table 3-26** shows the average fecal coliform production per animal, per day, contributed by each type of wildlife. Separation of the wildlife daily fecal coliform load into direct and indirect deposits was based on estimates of the amount of time each type of wildlife spends on land versus time spent in the stream. **Table 3-26** also shows the percent of time each type of wildlife spends in the stream on a daily basis.

Table 3-26: Fecal Coliform Production from Wildlife

Wildlife	Daily Fecal Production (in millions of cfu/day)	Portion of the Day in Stream (%)
Deer	347	1
Raccoon	113	10
Muskrat	25	50
Goose	799	50
Beaver	0.2	90
Mallard	2,430	50
Wood Duck	2,430	75
Wild Turkey	93	5

Source: ASAE, 1998; Map Tech, Inc., 2000; EPA, 2001.

3.5.8 Pets

The contribution of fecal coliform loading from pets was also examined in the assessment of fecal coliform loading to Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River. The primary types of pets considered in this TMDL are cats and dogs. The number of pets residing in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and

Staunton River watershed was estimated based on the number of households in the watershed, assuming an average of 1.7 dogs and 2.2 cats per household. Using the estimates of the total number of households in the watershed previously noted, it was estimated a total of 69,289 cats and 53,542 dogs were present in the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River watersheds.

Fecal coliform loading from pets occurs primarily in residential areas. The load was estimated based on daily fecal coliform production rates of 504 cfu/day per animal for cats and 4.09 $x10^9$ cfu/day per animal for dogs.

4.0 Modeling Approach

This section describes the modeling approach used in the TMDL development. The primary focus is on the sources represented in the model, assumptions used, model set-up, calibration, and validation, and the existing load.

4.1 Modeling Goals

The goals of the modeling approach were to develop a predictive tool for the water body that can:

- represent the watershed characteristics
- represent the point and non-point sources of fecal coliform and their respective contribution
- use input time series data (rainfall and flow) and kinetic data (die-off rates of fecal coliform)
- estimate the in-stream pollutant concentrations and loadings under the various hydrologic conditions
- allow for direct comparisons between the in-stream conditions and the water quality standard

4.2 Watershed Boundaries

The four impaired streams are located in the Staunton River Basin (USGS Cataloging Unit 03010101 and 03010102). The impaired segment of the Staunton River begins in Campbell County and flows through the borders of Campbell and Pittsylvania Counties into the borders of Halifax and Charlotte Counties. Cub Creek, Turnip Creek, and Buffalo Creek (UT) are tributaries to the Staunton River and are located in Charlotte County.

The watershed that encompasses the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River bacteria impairments is approximately 1,477,287 acres or 2,308 square miles. The watershed drains portions of Bedford, Franklin, Henry, Campbell, Pittsylvania, Appomattox, Charlotte, and Halifax counties. **Figure 4-1** shows the boundaries of the watershed that encompasses the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River.

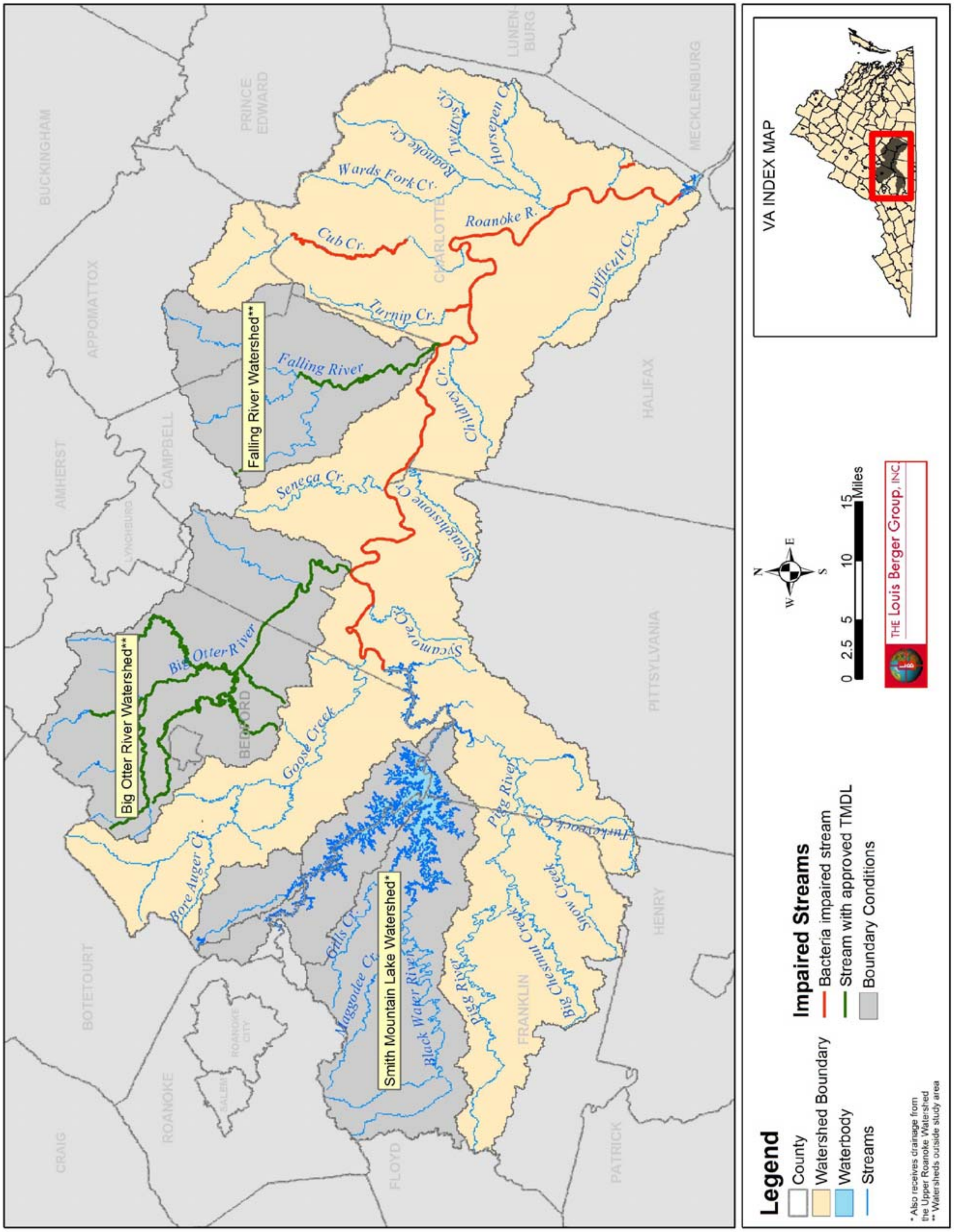


Figure 4-1: Watershed Boundary

4.3 Modeling Strategy

4.3.1 Model Selection

The Hydrologic Simulation Program-Fortran (HSPF) model was selected and used to predict the in-stream water quality conditions under varying scenarios of rainfall and fecal coliform loading. The results from the developed model are subsequently used to develop the TMDL allocations based on the existing fecal coliform load.

HSPF is a hydrologic, watershed-based water quality model. Consequently, HSPF can explicitly account for the specific watershed conditions, the seasonal variations in rainfall and climate conditions, and activities and uses related to fecal coliform loading.

The modeling process in HSPF starts with the following steps:

- delineate the watershed into smaller subwatersheds
- enter the physical data that describe each subwatershed and stream segment
- enter values for the rates and constants that describe the sources and the activities related to the fecal coliform loading in the watershed

These steps are discussed in the next sections.

4.3.2 Modeling Approach – Boundary Conditions

As mentioned in Section 3.2.1, bacteria TMDLs have already been approved for six impaired streams in the watershed. Five of the impaired streams flow into the Big Otter River (Machine Creek, Elk Creek, Sheep Creek, Little Otter River, Big Otter River), which then flow into the Staunton River just upstream of the Campbell County/Pittsylvania County line. The other impairment flows through Falling River into the Staunton River at the border of Campbell, Charlotte, and Halifax Counties.

The TMDLs developed in this study will include the results of the bacteria TMDLs developed for the Big Otter River and the Falling River watersheds. In addition, flow and water quality data from the American Electric Power (AEP) Leesville Power Plant (outlet of the Smith Mountain Lake Watershed) is also used for the development of these TMDLS. In other words, hydrology and water quality information from the Falling River Watershed, the Big Otter Watershed, and the Smith Mountain Lake Watershed are used as boundary conditions to the HSPF model simulating hydrology and water quality in the study area. **Table 4-1** depicts the hydrology and water quality sources used at each of the boundary conditions.

Table 4-1: Sources for Boundary Conditions

Boundary Watershed	Hydrology Data	Water Quality Data
Falling River	USGS 0206500	Fecal Loads from Falling River TMDL
Big Otter River	USGS 0262000	Fecal Loads from Big Otter TMDL
Smith Mountain Lake	AEP Leesville Power Plant	AEP Leesville Power Plant

4.4 Watershed Delineation

For this TMDL, the river watershed was delineated into 82 smaller subwatersheds to represent the watershed characteristics and to improve the accuracy of the HSPF model. This delineation was based on topographic characteristics, and was created using a Digital Elevation Model (DEM), stream reaches obtained from the RF3 dataset and the National Hydrography Dataset (NHD), and stream flow and in-stream water quality data. Size distributions of the 82 subwatersheds are presented in **Table 4-2.** **Figure 4-2** is a map showing the delineated subwatersheds for Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River.

Table 4-2: Subwatersheds Delineation

Sub-watershed	Drainage Area (acres)	Sub-watershed	Drainage Area (acres)
1	8,040	42	7,904
2	6,719	43	8,245
3	3,267	44	19,367
4	767	45	7,717
5	2,173	46	7,748
6	5,559	47	24,466
7	1,067	48	13,784
8	2,682	49	854
9	2,800	50	10,200
10	6,008	51	44,992
11	1,566	52	18,158
12	2,028	53	8,000
13	5,621	54	13,788
14	8,239	55	12,404
15	11,316	56	38,845
16	3,217	57	14,632
17	8,992	58	13,928
18	12,110	59	2,779
19	8,127	60	3,399
20	8,077	61	21,674
21	6,474	62	31,674
22	30,241	63	21,100
23	33,210	64	23,412
24	13,645	65	14,743
25	12,281	66	16,940
26	12,414	67	26,550
27	23,007	68	11,411
28	7,654	69	39,374
29	2,506	70	575
30	24,411	71	40,838
31	13,957	72	24,532
32	23,772	73	2,584
33	4,077	74	8,296
34	2,303	75	18,195
35	4,934	76	23,576
36	21,680	77	21,334
37	3,463	78	17,446
38	398	79	7,577
39	3,853	80	19,594
40	2,686	81	22,944
41	36,763	82	2,536
Subtotal Acreage	392,104	**Subtotal Acreage**	688,113

Acreage Grand Total	**1,080,218**

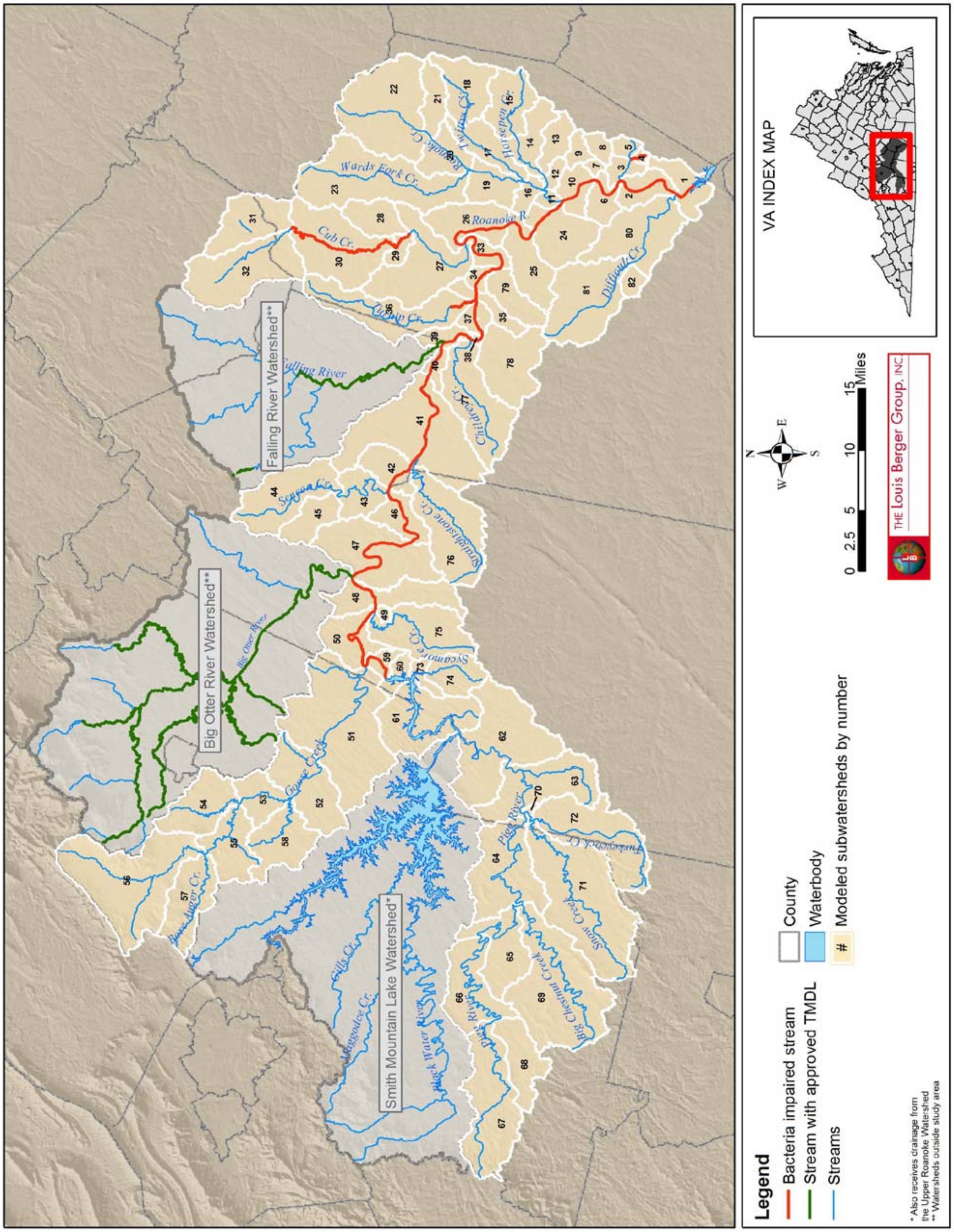


Figure 4-2: Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River Subwatershed Delineation

4.5 Land Use Reclassification

As previously mentioned, land use distribution in study area was determined using USGS NLCD data. The land use data and distribution of land uses were presented in Chapter 3. There are 12 land use classes present in the watershed; the dominant land uses are forested land and hay/pastureland. The original 12 land use types were consolidated into 7 land use categories to meet modeling goals, facilitate model parameterization, and reduce modeling complexity. This reclassification reduced the 12 land use types to a representative number of categories that best describe conditions and the dominant fecal coliform source categories in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. Land use reclassification was based on similarities in hydrologic characteristics and potential fecal coliform production characteristics. The reclassified land uses are presented in **Tables 4-3** through **4-6** for the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed respectively.

Table 4-3: Staunton River Land Use Reclassification

Land Use Category	Acres	Percent of Watershed's Land Area
Commercial/Industrial	2,753.5	0.3%
Cropland	28,020.8	2.8%
Forest	688,151.1	69.9%
High Density Residential	9.6	0.0%
Low Density Residential	7,270.3	0.7%
Pasture	228,982.4	23.3%
Water/Wetland	29,198.2	3.0%
Total	**984,385.8**	**100%**

Table 4-4: Cub Creek Land Use Reclassification

Land Use Category	Acres	Percent of Watershed's Land Area
Commercial/Industrial	45.7	0.1%
Cropland	1,367.3	1.9%
Forest	51,427.5	71.7%
High Density Residential	1.1	0.0%
Low Density Residential	316.9	0.4%
Pasture	15,947.9	22.2%
Water/Wetland	2,587.3	3.6%
Total	**71,693.7**	**100%**

Table 4-5: Turnip Creek Land Use Reclassification

Land Use Category	Acres	Percent of Watershed's Land Area
Commercial/Industrial	2.1	0.0%
Cropland	685.6	3.2%
Forest	1,4843.7	68.5%
Low Density Residential	45.5	0.2%
Pasture	5,188.5	23.9%
Water/Wetland	911.5	4.2%
Total	**21,676.8**	**100%**

Table 4-6: Buffalo Creek (UT) Land Use Reclassification

Land Use Category	Acres	Percent of Watershed's Land Area
Cropland	46.6	6.1%
Forest	464.4	60.5%
Pasture	243.2	31.7%
Water/Wetland	12.9	1.7%
Grand Total	**767.1**	**100%**

4.6 Hydrographic Data

Hydrographic data describing the stream network of Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton were obtained from the National Hydrography Dataset (NHD) and the Reach File Version 3 (RF3) dataset contained in BASINS. These data were used for HSPF model development and TMDL development. Information regarding the reach number, reach name, and length of each stream segment of Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River are included in the RF3 database. Due to the size of this basin, reach information for the entire Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River drainage is presented in Appendix B.

The stream geometry was field surveyed for representative reaches of Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River. The stage flow relationship required by HSPF was developed based on the USGS stream flow gage data for the Staunton River.

The Staunton River and its tributaries were represented as trapezoidal channels. The channel slopes were estimated using the reach length and the corresponding change in elevation from DEM data. The flow was calculated using the Manning's equation using a 0.05 roughness coefficient. Model representation of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River stream reach segments is presented in Appendix C.

4.7 Fecal Coliform Sources Representation

This section demonstrates how the fecal coliform sources identified in Chapter 3 were included or represented in the model. These sources include permitted sources, human sources (failed septic systems and straight pipes), livestock, wildlife, pets, and land application of manure and biosolids.

4.7.1 Permitted Facilities

There are 29 individually permitted facilities and 5 residential permitted facilities located in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed, not including the Falling River and Big Otter Watersheds. The permit number, design flow, and status for each facility were presented in **Table 3-12**.

For TMDL development, average discharge flow values were considered representative of flow conditions at each permitted facility, and were used in HSPF model set-up and calibration. For TMDL allocation development, permitted facilities were represented as constant sources discharging at their design flow and permitted fecal coliform concentrations.

4.7.2 Failed Septic Systems

Failed septic system loading to Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River can be direct (point) or land-based (indirect or non-point), depending on the proximity of the septic system to the stream. In cases where the septic system is within the 20-foot stream buffer, the failed septic system was represented in the model as a constant source (similar to a permitted facility). As explained in Chapter 3, the total number of septic systems in the watershed was estimated at 26,039 systems. Based on GIS data, only 2,782 out of the 26,039 households on septic systems were located within the 200-foot stream buffer. Therefore, the failed septic system load was considered a land-based load in the watershed.

For TMDL development, it was assumed that a 3% failure rate for septic systems would be representative of conditions in the watershed. This corresponds to a total of 781 failed septic systems in the study area. To account for uncontrolled discharges in the watershed and failed septic systems within the stream buffer, a total of 116 straight pipes were included in the model. This estimate was based on field observations, discussions with DCR and DEQ, stakeholder comments, evaluation of the BST results, and 1990 Census data which indicated that approximately 16% of households in the watershed are on other treatment systems.

In each subwatershed, the load from failing septic systems was calculated as the product of the total number of septic systems, septic systems failure rate, flow rate of septic discharge, typical fecal concentration in septic outflow, and the average household size in the watershed. The septic systems' design flow of 75 gallons per person per day and a fecal coliform concentration of 10,000 cfu/100ml were used in the fecal coliform load calculations. Fecal coliform loading from failed septic systems that are not within the 20 buffer of the stream is considered to be a predominantly indirect source. Failed septic systems within the stream buffer and straight pipes were represented as constant sources of fecal coliform. **Table 4-7** shows the distribution of the septic systems and the straight pipes in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. The monthly load from septic systems is presented in Appendix C.

Table 4-7: Failed Septic Systems and Straight Pipes Assumed in Model Development

Sub-watershed ID	# of Septic Systems	# of Failed Septic Systems	# of Straight Pipes	Sub-watershed ID	# of Septic Systems	# of Failed Septic Systems	# of Straight Pipes
1	39	1	0	**42**	127	4	1
2	28	1	0	**43**	66	2	0
3	18	1	1	**44**	479	14	1
4	0	0	0	**45**	273	8	0
5	7	0	0	**46**	19	1	0
6	279	8	0	**47**	624	19	2
7	24	1	0	**48**	2,091	63	3
8	34	1	0	**49**	447	13	0
9	22	1	0	**50**	260	8	1
10	34	1	0	**51**	812	24	3
11	3	0	0	**52**	701	21	2
12	4	0	0	**53**	183	5	1
13	26	1	0	**54**	497	15	2
14	44	1	0	**55**	264	8	1
15	142	4	0	**56**	1,630	49	11
16	8	0	0	**57**	548	16	3
17	778	23	1	**58**	838	25	1
18	172	5	0	**59**	24	1	0
19	18	1	0	**60**	278	8	0
20	293	9	0	**61**	127	4	4
21	176	5	1	**62**	233	7	8
22	405	12	1	**63**	224	7	8
23	347	10	0	**64**	461	14	2
24	183	5	0	**65**	2,891	87	1
25	28	1	0	**66**	1,931	58	11
26	12	0	0	**67**	766	23	6
27	35	1	1	**68**	5	0	3
28	91	3	0	**69**	721	22	7
29	202	6	0	**70**	322	10	0
30	158	5	1	**71**	204	6	5
31	169	5	0	**72**	1,012	30	6
32	337	10	0	**73**	278	8	1
33	3	0	0	**74**	527	16	2
34	0	0	0	**75**	114	3	4
35	8	0	0	**76**	12	0	2
36	146	4	1	**77**	469	14	1
37	14	0	0	**78**	130	4	0
38	3	0	0	**79**	5	0	0
39	24	1	0	**80**	0	0	0
40	405	12	0	**81**	0	0	1
41	725	22	2	**82**	0	0	0

Total	**26,039**	**781**	**116**

4.7.3 Livestock

Livestock contribution to the total fecal coliform load in the watershed was represented in a number of ways, which are presented in **Figure 4-3**. The model accounts for fecal coliform directly deposited in the stream, fecal coliform deposited while livestock are in confinement and later spread onto the crop and pasture lands in the watershed (land application of manure), and finally, land-based fecal coliform deposited by livestock while grazing.

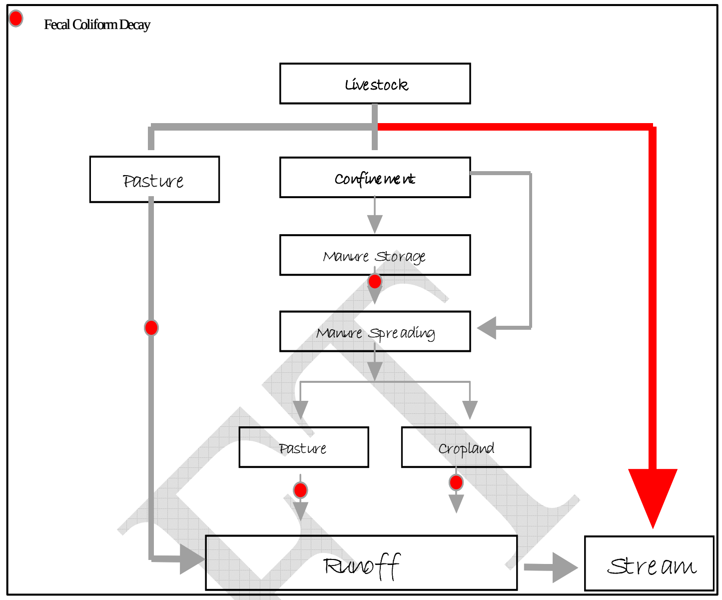


Figure 4-3: Livestock Contribution to Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River

Based on the inventory of livestock in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed, it was determined that beef cattle are the predominant type of livestock, though dairy cows are also present in the watershed. The inventory also indicated that there are no horses, goats, poultry operations, sheep, swine or feedlots in the watershed. Five dairy operations exist in the watershed. The survey also indicated that alternative water has been implemented in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed to minimize livestock activity in the stream.

The distribution of the daily fecal coliform load between direct in-stream and indirect (land-based) loading was based on livestock daily schedules. The direct deposition load from livestock was estimated from the number of livestock in the watershed, the daily fecal coliform production per animal, and the amount of time livestock spent in the stream. The amount of time livestock spend in the stream was presented in Chapter 3.

The land-based load of fecal coliform from livestock while grazing was determined based on the number of livestock in the watershed, the daily fecal coliform production per animal, and the percent of time each animal spends in pasture. The monthly loading rates are presented in Appendix C.

4.7.4 Land Application of Manure

Beef cattle, as well as several dairy operations, are present in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. Because there are no feedlots or large manure storage facilities present in the watershed, the daily produced manure is applied to pastureland in the watershed, and was treated as an indirect source in the development of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDL. Beef cattle spend the majority of their time on pastureland and are not confined. Thus, fecal coliform loading from beef cattle was accounted for via the methods described above. Dairy cattle do spend time in confinement, and their fecal coliform load was included in the calculation of land application of manure. Fecal coliform loading from land application of manure was estimated based on the total number of dairy cows in the watershed, the fecal coliform production per animal per day, and the percent of time dairy cows were in confinement.

4.7.5 Land Application of Biosolids

Biosolids application in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watersheds was considered under this TMDL development. Biosolids were modeled as land based loads applied to crop and pasture lands in each watershed. The loads modeled were based on county specific annual application estimates reported by the Virginia Department of Health.

4.7.6 Wildlife

Fecal loading from wildlife was estimated in the same way as loading from livestock. As with livestock, fecal coliform contributions from wildlife can be both indirect and direct. The distribution between direct and indirect loading was based on estimates of the amount of time each type of wildlife spends on the surrounding land versus in the stream.

Daily fecal coliform production per animal and the amount of time each type of wildlife spends in the stream was presented previously in the wildlife inventory (Chapter 3). The direct fecal coliform load from wildlife was calculated by multiplying the number of each type of wildlife in the watershed by the fecal coliform production per animal per day, and by the percentage of time each animal spends in the stream. Indirect (land-based) fecal coliform loading from wildlife was estimated as the product of the number of each type of wildlife in the watershed, the fecal coliform production per animal per day, and the percent of time each animal spends on land within the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. The resulting fecal coliform load was then distributed to forest and pasture land uses, which represent the most likely areas in the watershed where wildlife would be present and defecate. This was accomplished by converting the indirect fecal coliform load to a unit loading (cfu/acre), then multiplying the unit loading by the total area of forest and pasture in each subwatershed.

4.7.7 Pets

For the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDL, pet fecal coliform loading was considered a land-based load that was primarily deposited in residential areas of the watershed. The daily fecal coliform loading was calculated as the product of the number of pets in the watershed and the daily fecal coliform production per type of pet.

4.8 Fecal Coliform Die-off Rates

Representative fecal coliform decay rates were included in the HSPF model developed for the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. Three fecal coliform die-off rates required by the model to accurately represent watershed conditions included:

1. **In-storage fecal coliform die-off**. Fecal coliform concentrations are reduced while manure is in storage facilities.

2. **On-surface fecal coliform die-off**. Fecal coliform deposited on the land surfaces undergoes decay prior to being washed into streams.

3. **In-stream fecal coliform die-off**. Fecal coliform directly deposited into the stream, as well as fecal coliform entering the stream from indirect sources, will also undergo decay.

In the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDL, in-storage die-off was not included in the model because there is no manure storage facility located in the watershed. Decay rates of 1.37 and 1.152 per day were used to estimate die-off rates for on-surface and in-stream fecal coliform, respectively (EPA, 1985).

4.9 Model Set-up, Calibration, and Validation

Hydrologic calibration of the HSPF model involves the adjustment of model parameters to control various flow components (e.g. surface runoff, interflow and base flow, and the shape of the hydrographs) and make simulated values match observed flow conditions during the desired calibration period.

The model credibility and stakeholder faith in the outcome hinges on developing a model that has been calibrated and validated. Model calibration is a reality check. The calibration process compares the model results with observed data to ensure the model output is accurate for a given set of conditions. Model validation establishes the model's credibility. The validation process compares the model output to the observed data set, which is different from the one used in the calibration process, and estimates the model's prediction accuracy. Water quality processes were calibrated following calibration of the hydrologic processes of the model.

4.9.1 Model Set-Up

The HSPF model was set up and calibrated based on flow data taken at two USGS stations within the watershed. The USGS streamflow stations were presented in Section 3.3. The two selected calibrations stations are presented in **Table 4-8**.

Table 4-8: USGS Flow Stations used for Hydrology Calibration and Validation

Station ID	Station Name	Area (mi^2)	Begin Date	End Date
02059500	Goose Creek near Huddleston, VA	188	10/01/1930	04/30/2005
02066000	Staunton River at Randolph, VA	1,300*	10/01/1901	04/30/2005

* excluding areas from the Big Otter, Falling River, and Smith Mountain Lakes watersheds

4.9.1.1 Stream Flow Data

These two stations were selected because of their locations within the watershed. Station 02059500 (Goose Creek near Huddleston, VA) has a drainage are of 188 square miles and is the most upstream station, with continuous record, from the impaired segment of the Staunton River. Station 02066000 Staunton River at Randolph, VA) drains 1,300 square miles (excluding Big Otter, Falling River, and Smith Mountain Lakes watershed), is the most downstream station with continuous records, and drains Turnip Creek and Cub Creek; the two other impaired segments within the study area. The entire drainage area of the area of concern is 1,688 square miles. In other words, the two flow stations selected for the hydrology calibration and verification capture the complete hydrologic response within the study area. Average flow data for the period of 1995 to 2004 for these two stations are plotted in **Figures 4-4** and **4-5.**

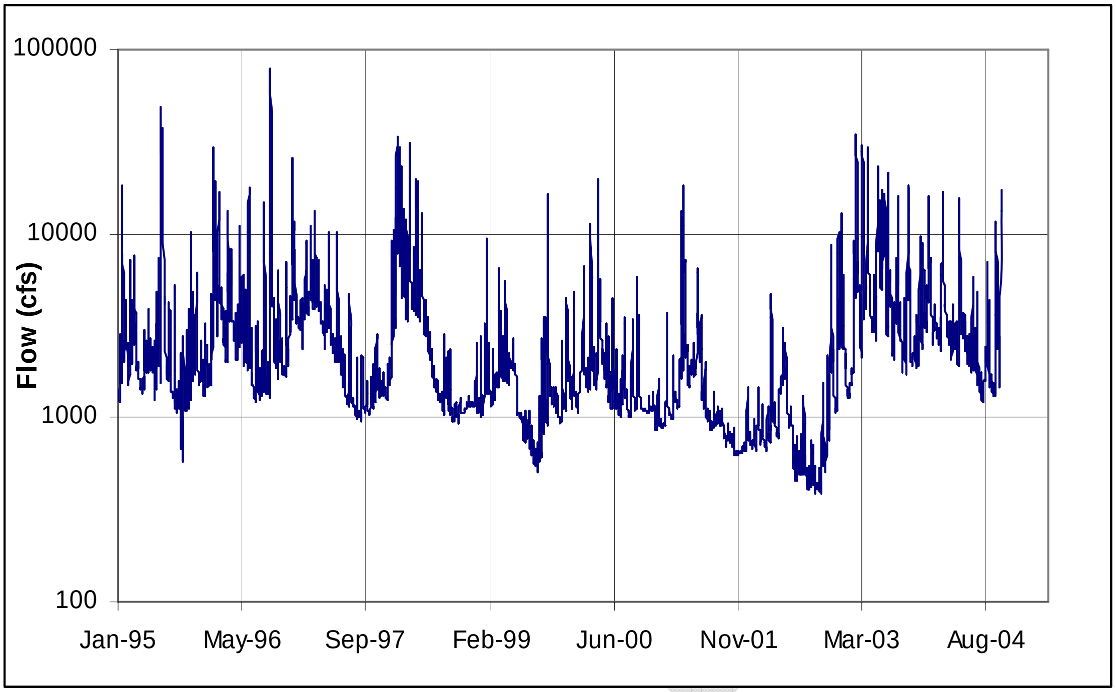


Figure 4-4: Daily Mean Flow at USGS Station 02066000 Staunton River at Randolph, VA

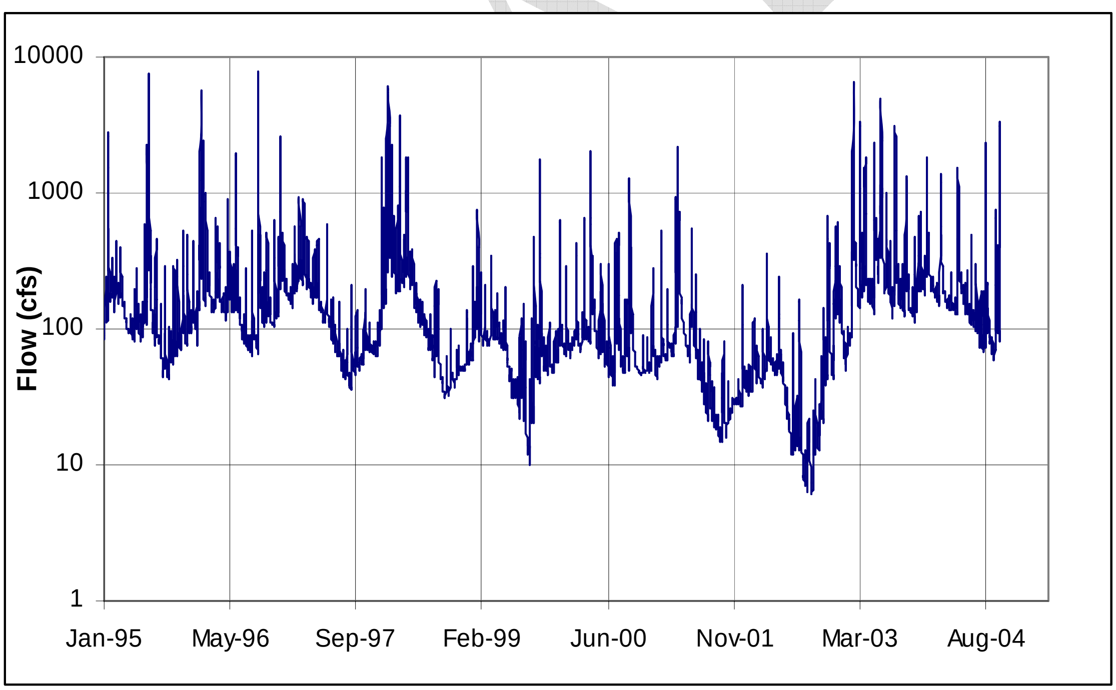


Figure 4-5: Daily Mean Flow at USGS Station 02959500 (Goose Creek near Huddleston, VA)

A 4-year period (1995-1999) was selected as the calibration period for Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton hydrologic model. The validation period selected spans from 2000 to 2004.

4.9.1.2 Rainfall and Climate Data

Weather data for the Roanoke International Airport, the Lynchburg WSO Airport, and the John H. Kerr Dam were obtained from NCDC. The data include meteorological data (hourly precipitation) and surface airways data (including wind speed/direction, ceiling height, dry bulb temperature, dew point temperature, and solar radiation). For this TMDL, the recorded data at the three stations were combined based on their proximity to each model segment in the watershed. After several iterations of weighted-combinations of the data from the three stations, the final weather-stations combined record for each segment is shown in **Table 4-9** and depicted in **Figure 4-6**.

Table 4-9: Proportion of Rainfall from each Gauging Stations used for Hydrology Calibration and Validation

Model Segments	Lynchburg WSO Airport (%)	Roanoke Airport (%)	John Kerr Dam (%)
1 to 50	50	0	50
51 to 59	50	50	0
60 to 74	0	100	0
75 to 82	50	0	50

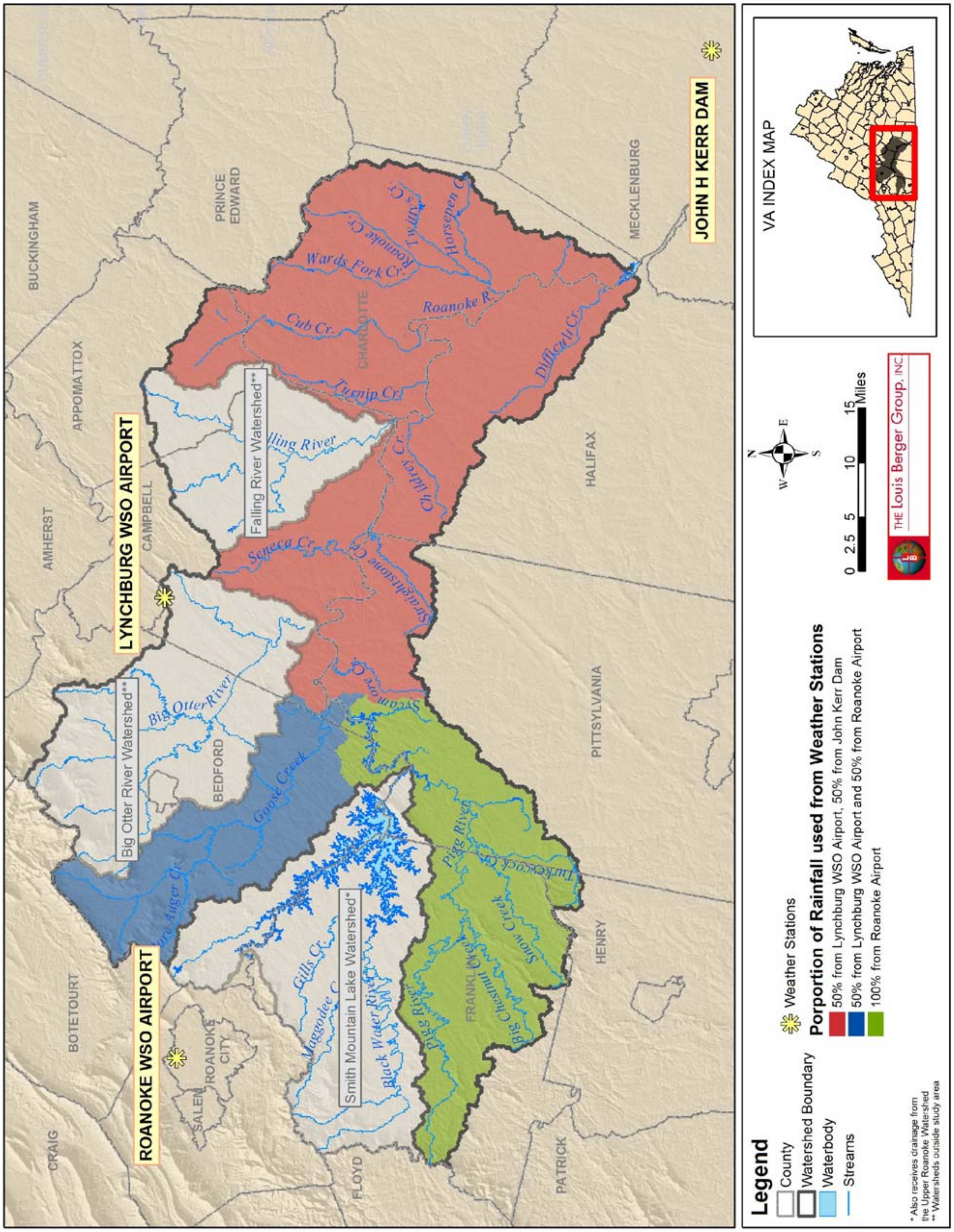


Figure 4-6: Location of Rainfall Stations and Rainfall and Proportion of Rainfall from each Stations

4.9.2 Model Hydrologic Calibration Results

HSPEXP software was used to calibrate the hydrology of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. After each iteration of the model, summary statistics were calculated to compare model results with observed values, in order to provide guidance on parameter adjustment according to built-in rules. The rules were derived from the experience of expert modelers and listed in the HSPEXP user manual (Lumb and Kittle, 1993).

Using the recommended default criteria as target values for an acceptable hydrologic calibration, the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River model was calibrated for January 2000 to December 2001 at the flow stations 02059500 (Goose Creek near Huddleston, VA) and 02066000 Staunton River at Randolph, VA. Calibration results at station USGS 02059500 are presented in **Table 4-10**, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is presented in **Table 4-11**. The breakdown of the overall percent base, storm and interflow contribution is presented in **Table 4-12**. The model results and the observed daily average flow at the two calibration stations are plotted in **Figure 4-7** and **4-8**.

Table 4-10: USGS 02059500 (Goose Creek near Huddleston, VA) Model Calibration Results

Category	Simulated	Observed
Total runoff, in inches	14.54	13.549
Total of highest 10% flows, in inches	4.830	5.309
Total of lowest 50% flows, in inches	2.950	3.071
Total storm volume, in inches	1.570	1.961
Average of storm peaks, in cfs	439.10	531.00
Baseflow recession rate	0.97	0.96
Summer flow volume, in inches	3.51	2.496
Winter flow volume, in inches	3.23	2.965
Summer storm volume, in inches	0.24	0.186

Table 4-11: USGS 02059500 (Goose Creek near Huddleston, VA) Model Calibration Error Statistics

Category	Current	Criterion
Error in total volume	7.3	± 10.000
Error in low flow recession	-0.01	± 0.01
Error in 50% lowest flows	-3.9	± 10.000
Error in 10% highest flows	-9.0	± 15.000

Table 4-12: USGS 02059500 (Goose Creek near Huddleston, VA) Simulation Water Budget

Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
2000	0.34	2.00	6.80	4%	22%	74%
2001	0.19	1.00	4.20	4%	19%	78%
Average	**0.27**	**1.50**	**5.50**	**4%**	**20%**	**76%**

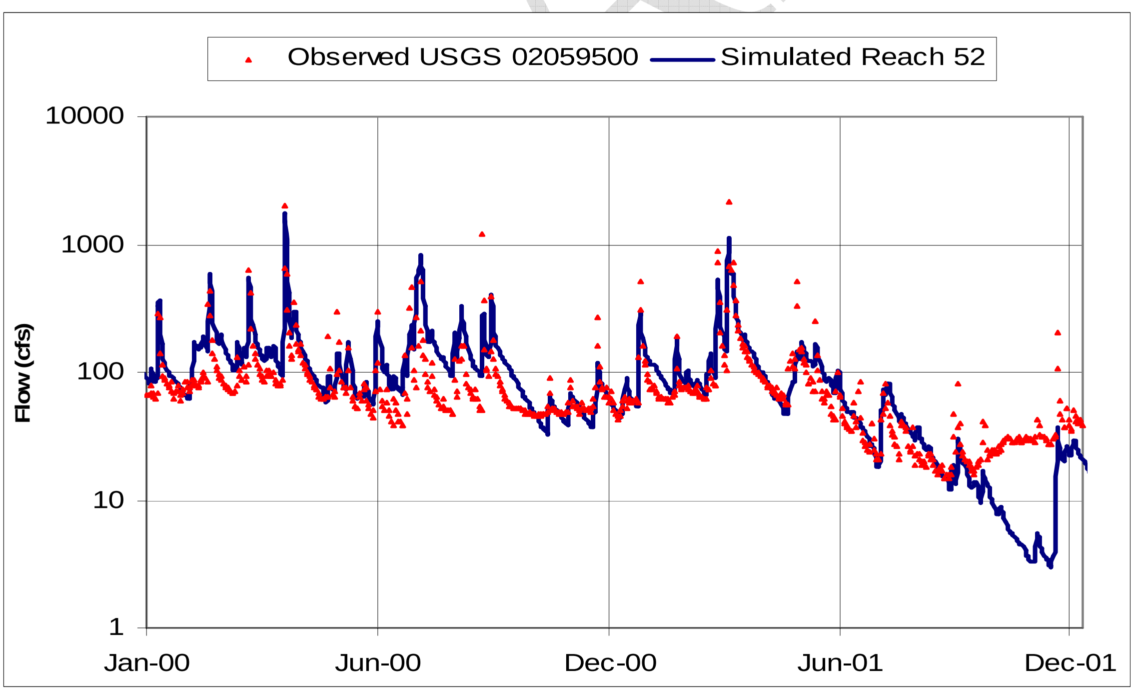


Figure 4-7: USGS 02059500 (Goose Creek near Huddleston, VA) Model Hydrologic Calibration Results

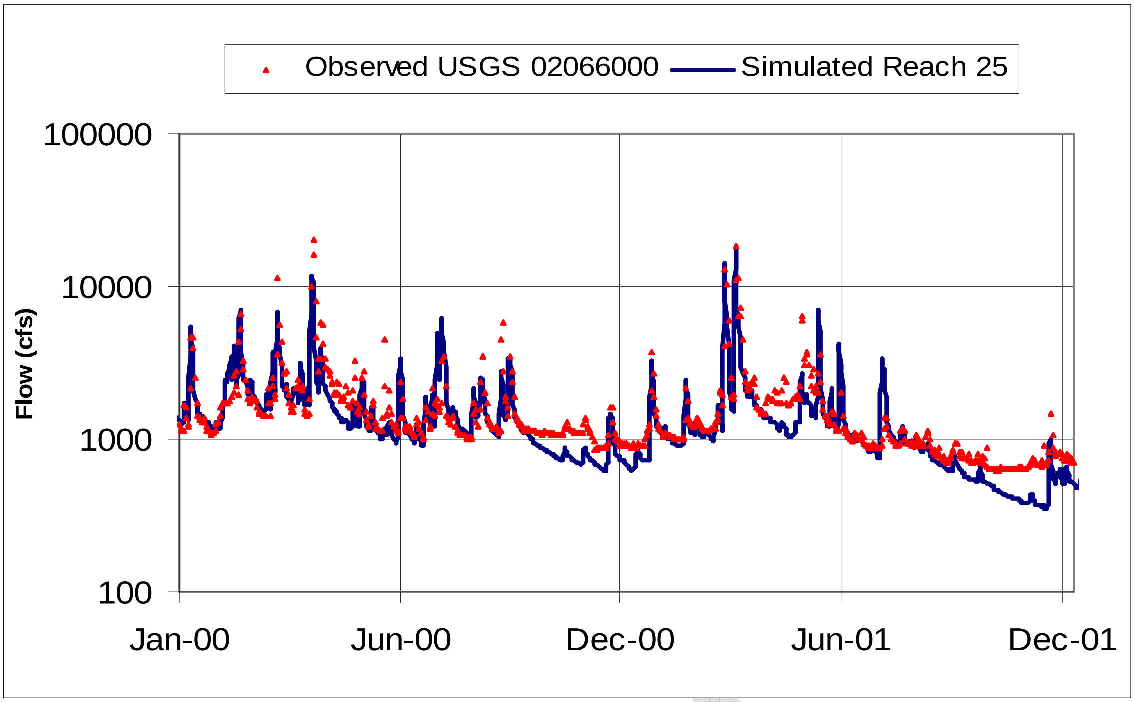


Figure 4-8: USGS 02066000 Staunton River at Randolph, VA Model Hydrologic Calibration Results

4.9.3 Model Hydrologic Validation Results

The period of January 2001 to December 2004 was used to validate the HSPF model. Model validation results at the USGS Station 02059500 are presented in **Table 4-13**, showing the simulated and observed values for nine flow characteristics. An error statistics summary for seven flow conditions is also presented for this station in **Table 4-14**.

The error statistics indicate that the validation results were within the recommended ranges in HSPF. The breakdown of the overall percent base, storm and interflow contribution is presented in **Table 4-15** for the USGS Station 02059500. The model's hydrology validation results are plotted in **Figure 4-9** and **4-10**.

Table 4-13: USGS 02059500 (Goose Creek near Huddleston, VA) Model Validation Results

Category	Simulated	Observed
Total runoff, in inches	46.350	45.554
Total of highest 10% flows, in inches	19.960	20.412
Total of lowest 50% flows, in inches	7.750	7.090
Total storm volume, in inches	12.960	12.635
Average of storm peaks, in cfs	1317.305	1047.273
Baseflow recession rate	0.96	0.96
Summer flow volume, in inches	10.80	11.931
Winter flow volume, in inches	12.390	11.937
Summer storm volume, in inches	2.550	3.208

Table 4-14: USGS 02059500 (Goose Creek near Huddleston, VA) Model Validation Error Statistics

Category	Current	Criterion
Error in total volume	1.70	± 10.000
Error in low flow recession	-0.00	± 0.01
Error in 50% lowest flows	9.3	± 10.000
Error in 10% highest flows	-2.20	± 15.000

Table 4-15: USGS 02059500 (Goose Creek near Huddleston, VA) Validation Water Budget

Year	Surface Runoff (inch)	Interflow (inch)	Base flow (inch)	Surface runoff	Interflow	Base flow
2002	0.20	0.90	4.10	4%	17%	79%
2003	1.94	11.70	13.20	7%	44%	49%
2004	0.58	4.40	7.70	5%	35%	61%
Average	**0.90**	**5.67**	**8.33**	**5%**	**32%**	**63%**

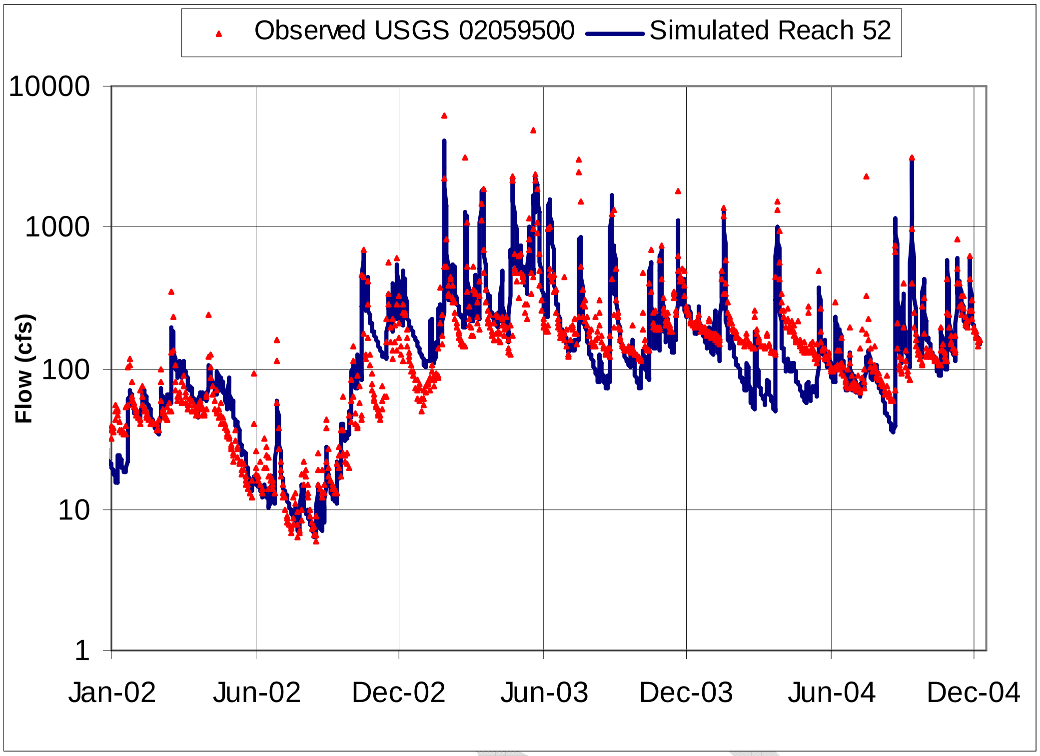


Figure 4-9: USGS 02059500 (Goose Creek near Huddleston, VA) Model Hydrologic Calibration Results

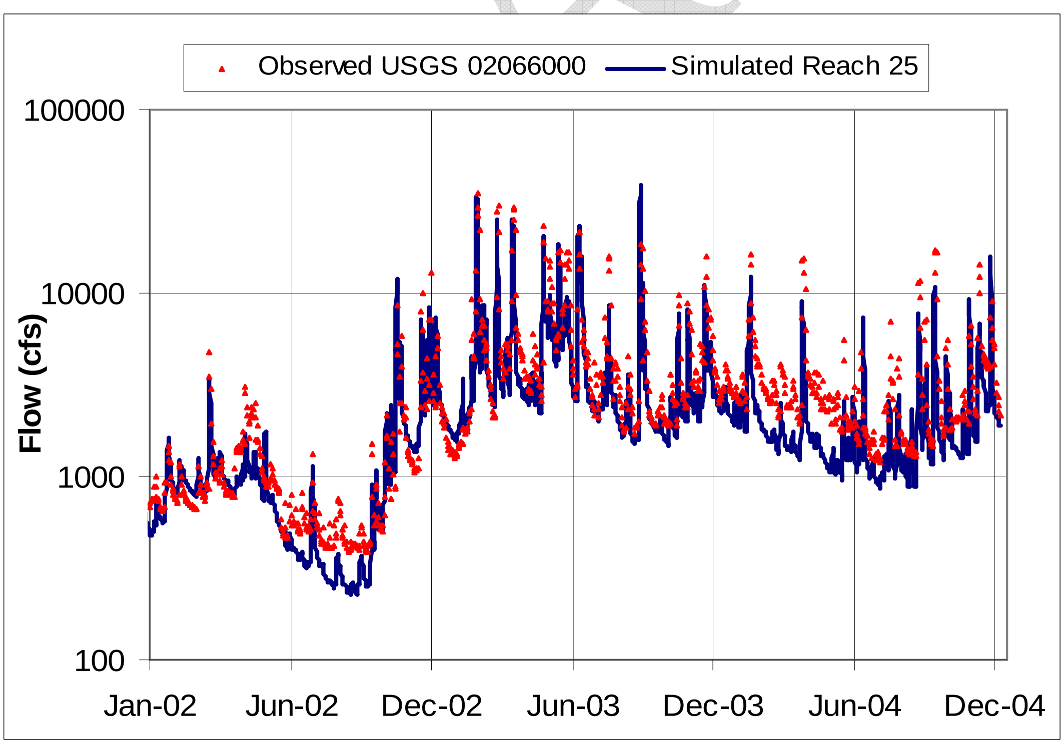


Figure 4-10: USGS 02066000 Staunton River at Randolph, VA - HSPF Model Hydrologic Validation Results

There is good agreement between the observed and simulated stream flow, indicating that the model parameterization is representative of the hydrologic characteristics of the watershed. Model results closely match the observed flows during low flow conditions, base flow recession, and storm peaks. The final parameter values of the calibrated model are listed in **Table 4-16**.

Table 4-16: Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River HSPF Calibration Parameters (Typical, Possible and Final Values)

Parameter	Definition	Units	Typical		Possible		Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River
			Min	Max	Min	Max	
FOREST	Fraction forest cover	None	0.00	0.5	0	0.95	0.0-1.0
LZSN	Lower zone nominal soils moisture	inch	3	8	2	15	5.0-6.5
INFILT	Index to infiltration capacity	Inch/hour	0.01	0.25	0.001	0.5	0.05-0.07
LSUR	Length of overland flow	Ft	200	500	100	700	250-300
SLSUR	Slope of overland flowplane	None	0.01	0.15	0.001	0.3	0.0949 - 0.0949
KVARY	Groundwater recession variable	1/inch	0	3	0	5	0
AGWRC	Basic groundwater recession	None	0.92	0.99	0.85	0.999	0.955 - 0.99
PETMAX	Air temp below which ET is reduced	Deg F	35	45	32	48	40
PETMIN	Air temp below which ET is set to zero	Deg F	30	35	30	40	35
INFEXP	Exponent in infiltration equation	None	2	2	1	3	2
INFILD	Ratio of max/mean infiltration capacities	None	2	2	1	3	2
DEEPER	Fraction of groundwater inflow to deep recharge	None	0	0.2	0	0.5	0.05 - 0.28
BASETP	Fraction of remaining ET from base flow	None	0	0.05	0	0.2	0.02
AGWETP	Fraction of remaining ET from active groundwater	None	0	0.05	0	0.2	0 – 0

Parameter	Definition	Units	Typical		Possible		Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River
			Min	Max	Min	Max	
CEPSC	Interception storage capacity	Inch	0.03	0.2	0.01	0.4	0.05
UZSN	Upper zone nominal soils moisture	inch	0.10	1	0.05	2	0.7 - 1.2
NSUR	Manning's n	None	0.15	0.35	0.1	0.5	0.25
INTFW	Interflow/surface runoff partition parameter	None	1	3	1	10	1.7 - 3.5
IRC	Interflow recession parameter	None	0.5	0.7	0.3	0.85	0.25 - 0.65
LZETP	Lower zone ET parameter	None	0.2	0.7	0.1	0.9	0.4 - 0.6
RETSC	Retention storage capacity of the surface	inch					0.065
ACQOP	Rate of accumulation of constituent	#/ac day					2.64E7 – 2.86E10
SQOLIM	Maximum accumulation of constituent	#					5.81E7 – 6.30E10
WSQOP	Wash-off rate	Inch/hour					0.4 - 0.8
IOQC	Constituent concentration in interflow	#/CF					1416
AOQC	Constituent concentration in active groundwater	#/CF					283
KS	Weighing factor for hydraulic routing						0.5
FSTDEC	First order decay rate of the constituent	1/day					1.152
THFST	Temperature correction coefficient for FSTDEC	none					1.07

4.9.4 Water Quality Calibration

Calibrating the water quality component of the HSPF model involves setting up the build-up, wash-off, and kinetic rates for fecal coliform that best describe fecal coliform sources and environmental conditions in the watershed. It is an iterative process in which the model results are compared to the available in-stream fecal coliform data, and the model parameters are adjusted until there is an acceptable agreement between the observed and simulated in-stream concentrations and the build-up and wash-off rates are within the acceptable ranges.

The availability of water quality data is a major factor in determining calibration and validation periods for the model. In Chapter 3, in-stream monitoring stations on the impaired segments were listed and sampling events conducted on Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River were summarized and presented. **Table 4-17** lists the stations used in the water quality calibration.

Table 4-17: Water Quality Station used in the HSPF Fecal Coliform Simulations

Watershed	Water Quality Station	HSPF Model segment
Cub Creek	4ACUB010.96	30
Turnip Creek	4ATIP002.55	36
Buffalo Creek (UT)	4XMC000.54	4
Staunton	4AROA129.55	49
Staunton	4AROA097.46	41
Staunton	4AROA059.12	6

The period used for water quality calibration of the model, and the period used for model validation depended on the time the water quality observations wee collected. It is important to keep in mind that the observed fecal coliform concentrations are instantaneous values that are highly dependent on the time and location the sample was collected. The model-simulated fecal coliform concentrations represent the average daily values. For clarity reasons, the Figure numbers depicting the results of the water quality calibration and validation at each station are referenced in **Table 4-18**. These twelve (12)

Figures, (2 per station; one for calibration and one for validation) summarize the results of the HSPF fecal coliform simulations.

Table 4-18: References to Figures Depicting Water Quality Calibration and Validation

Water Quality Station	Watershed	Calibration	Validation
4ACUB010.96	Cub Creek	**Figure 4-11**	**Figure 4-12**
4ATIP002.55	Turnip Creek	**Figure 4-13**	**Figure 4-14**
4XMC000.54	Buffalo Creek (UT)	**Figure 4-15**	**Figure 4-16**
4AROA129.55	Staunton	**Figure 4-17**	**Figure 4-18**
4AROA097.46	Staunton	**Figure 4-19**	**Figure 4-20**
4AROA059.12	Staunton	**Figure 4-21**	**Figure 4-22**

The goodness of fit for the water quality calibration was evaluated visually. Analysis of the model results indicated that the model was capable of predicting the range of fecal coliform concentrations under both wet and dry weather conditions, and thus was well-calibrated. **Table 4-19** shows the observed and simulated geometric mean fecal coliform concentration spanning the period from 2000 to 2004. **Table 4-20** shows the observed and simulated exceedance rates of the 400 cfu/100 ml instantaneous fecal coliform standard.

Table 4-19: Observed and Simulated Geometric Mean Fecal Coliform Concentration 2000-2004

Reach	Water Quality Station	Watershed	Geometric Mean (cfu/100ml)	
			Observed	Simulated
30	4ACUB010.96	Cub Creek	165.2	171.1
36	4ATIP002.55	Turnip Creek	174.4	147.9
4	4XMC000.54	Buffalo Creek (UT)	155.0	233.6
49	4AROA129.55	Staunton	125.2	96.7
41	4AROA097.46	Staunton	119.8	112.2
6	4AROA059.12	Staunton	119.8	123.6

Table 4-20: Observed and Simulated Exceedance Rates of the 400 cfu/100ml Instantaneous Fecal Coliform Standard

Reach	Water Quality Station	Watershed	Rate of Exceedance (%)	
			Observed	Simulated
30	4ACUB010.96	Cub Creek	25.0	18.5
36	4ATIP002.55	Turnip Creek	25.7	31.1
4	4XMC000.54	Buffalo Creek (UT)	10.1	10.0
49	4AROA129.55	Staunton	10.1	10.0
41	4AROA097.46	Staunton	9.7	21.6
6	4AROA059.12	Staunton	29.4	27.8

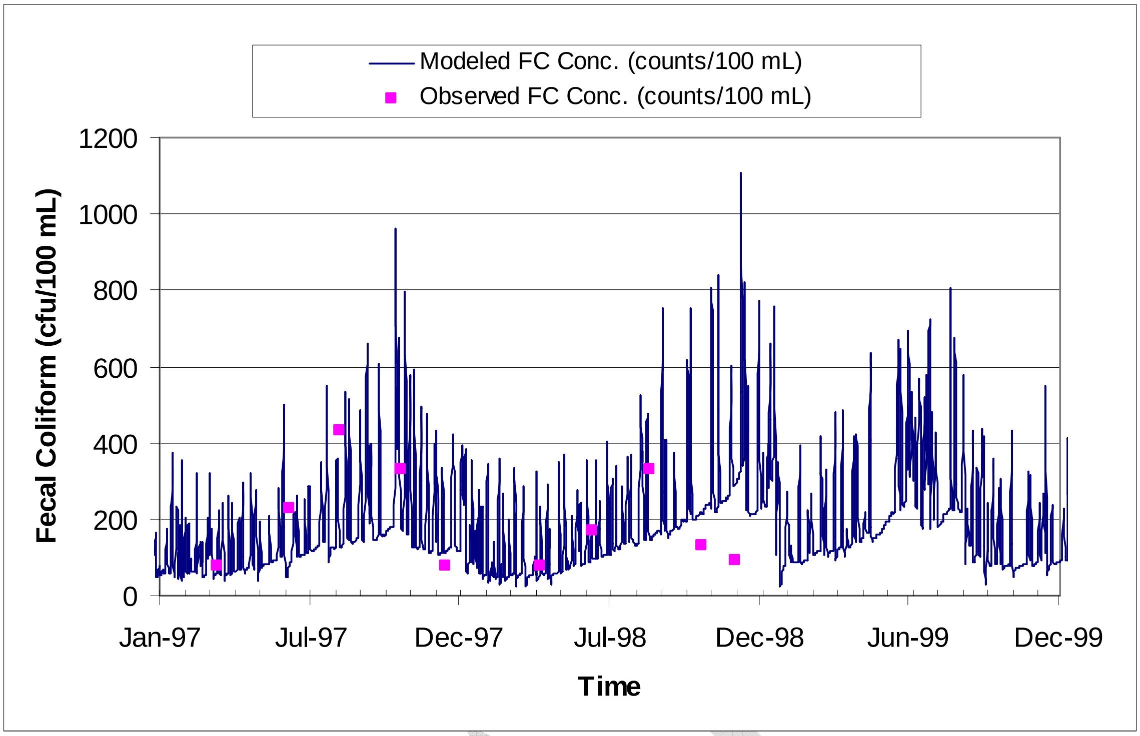


Figure 4-11: Fecal Coliform Calibration Cub Creek (Reach 30)

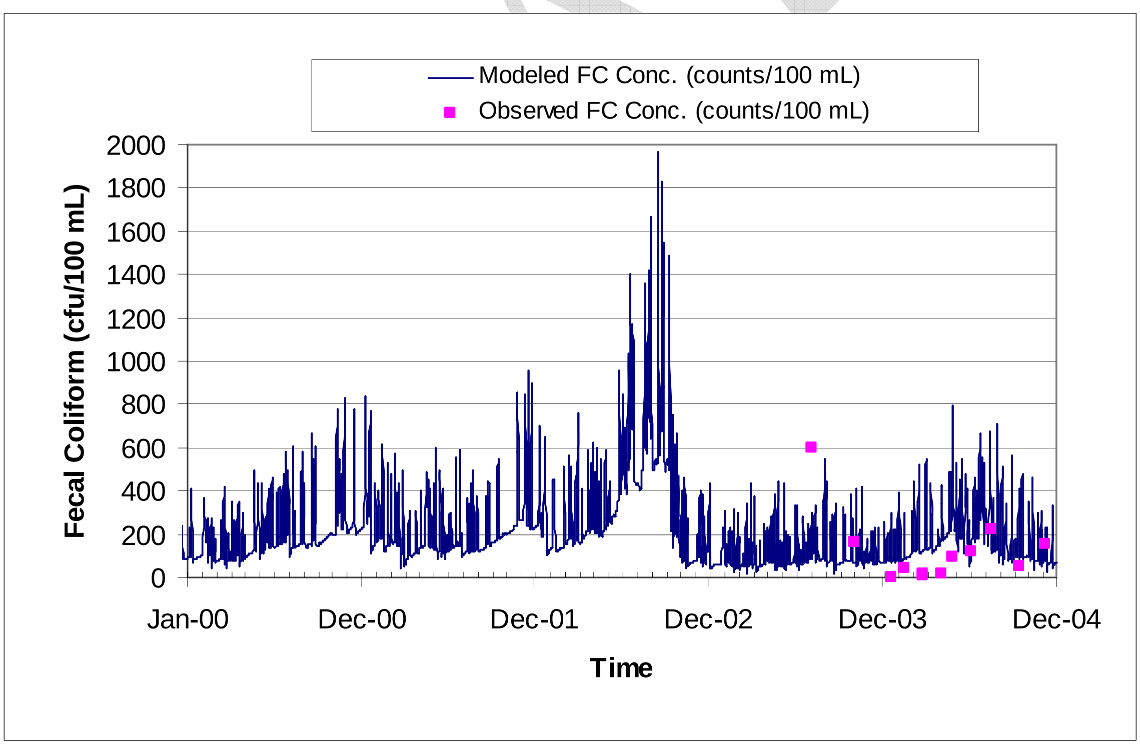


Figure 4-12: Fecal Coliform Validation Cub Creek (Reach 30)

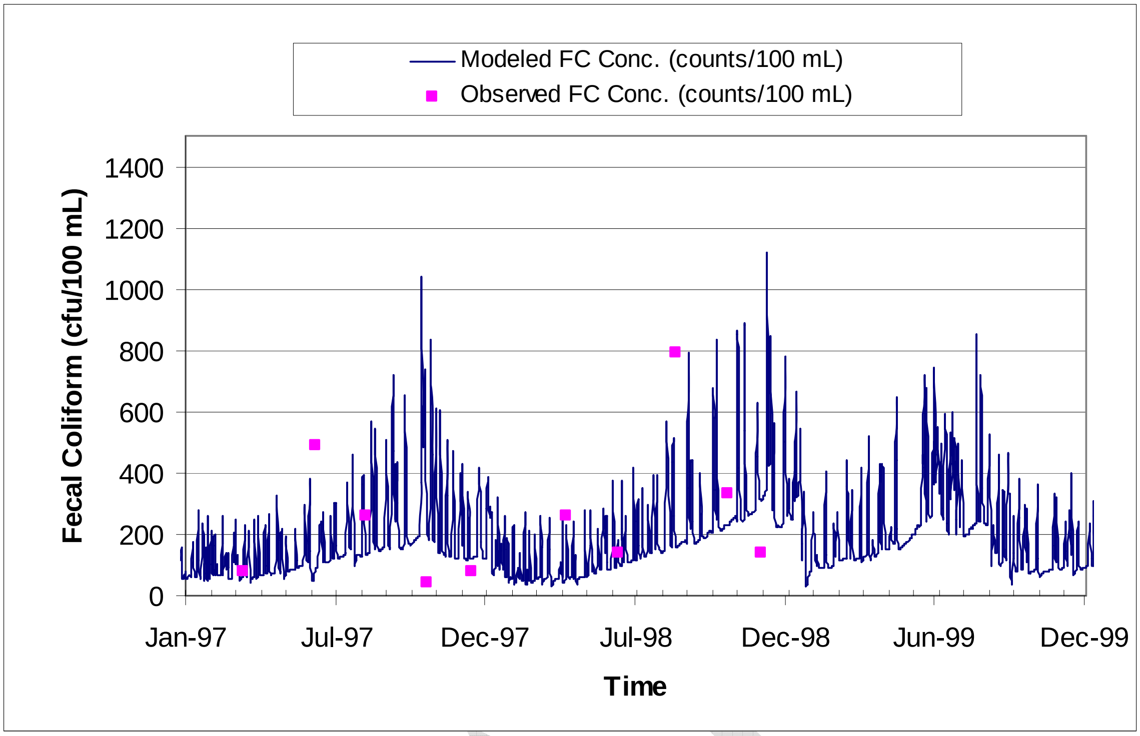


Figure 4-13: Fecal Coliform Calibration Turnip Creek (Reach 36)

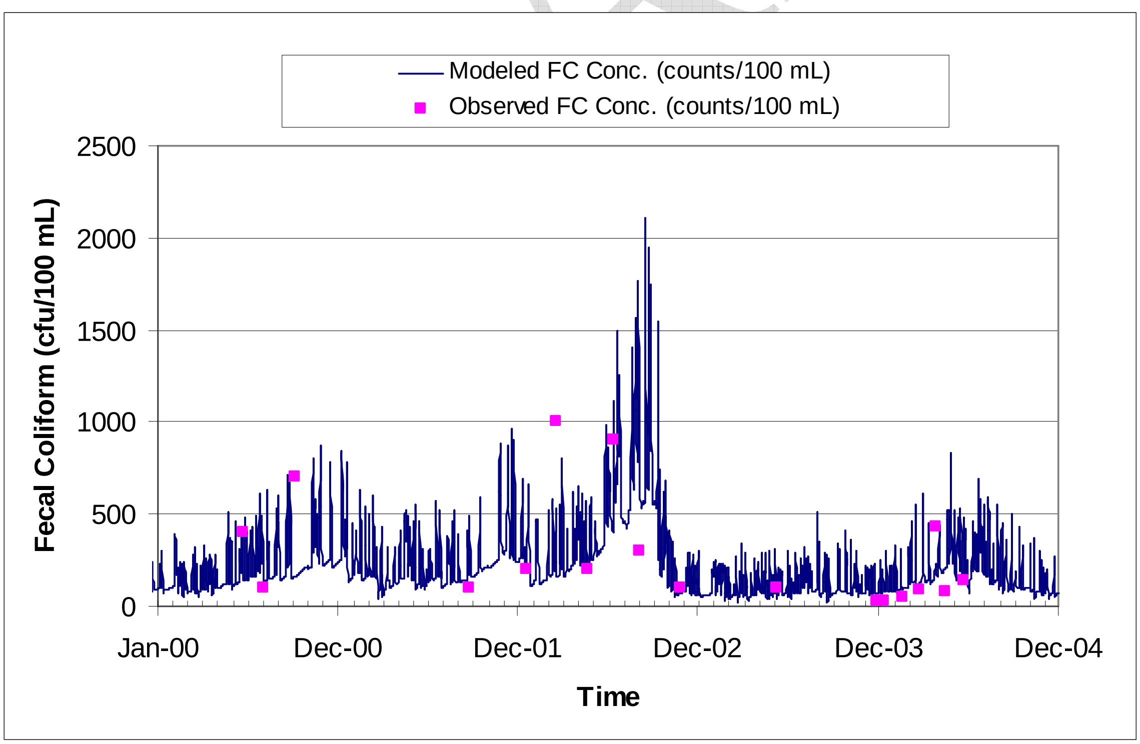


Figure 4-14: Fecal Coliform Validation Turnip Creek (Reach 36)

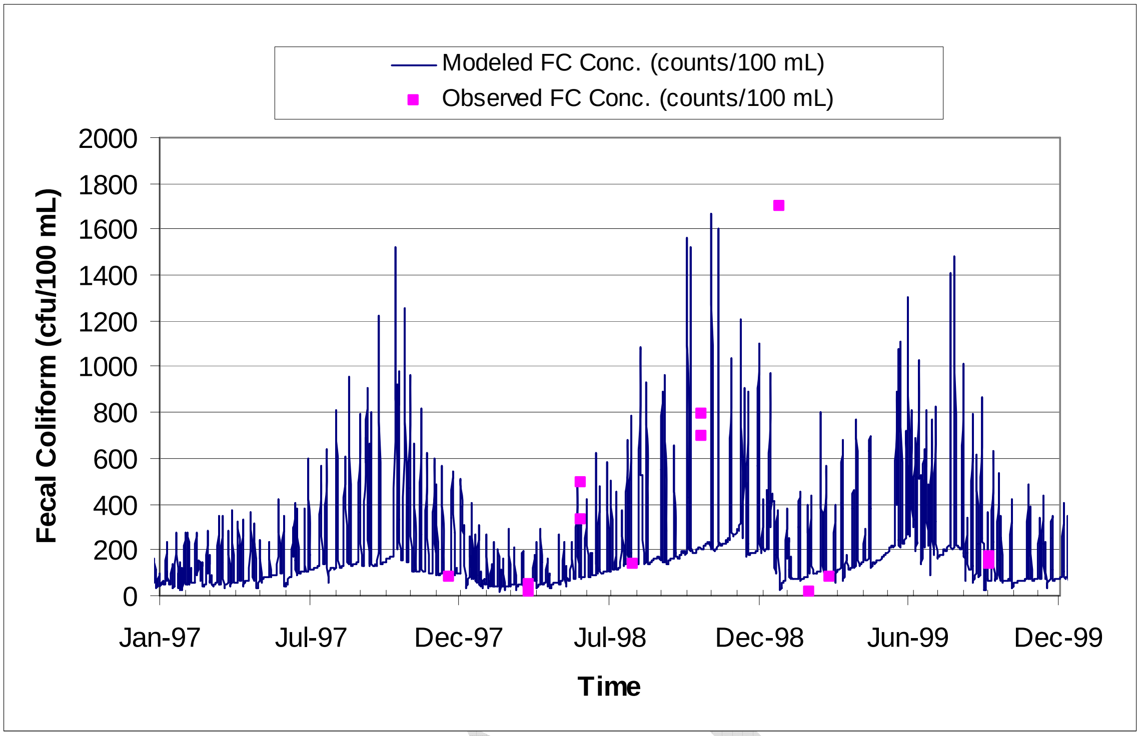


Figure 4-15: Fecal Coliform Calibration Buffalo Creek (UT) (Reach 4)

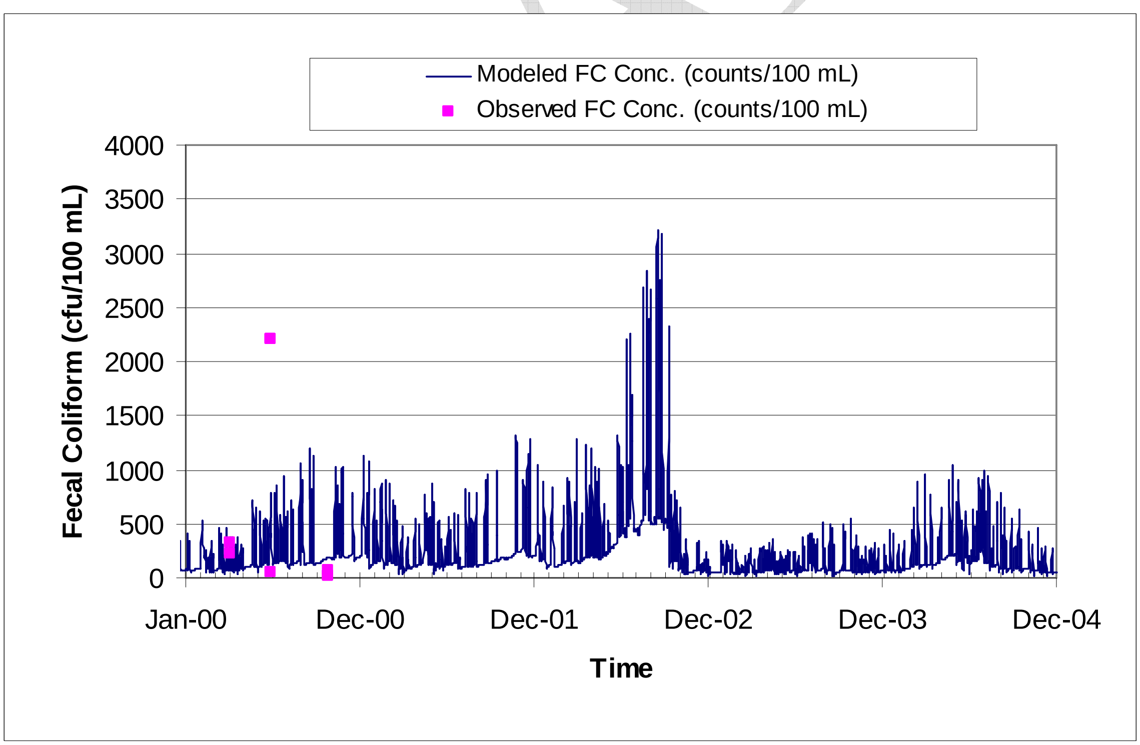


Figure 4-16: Fecal Coliform Validation Buffalo Creek (UT) (Reach 4)

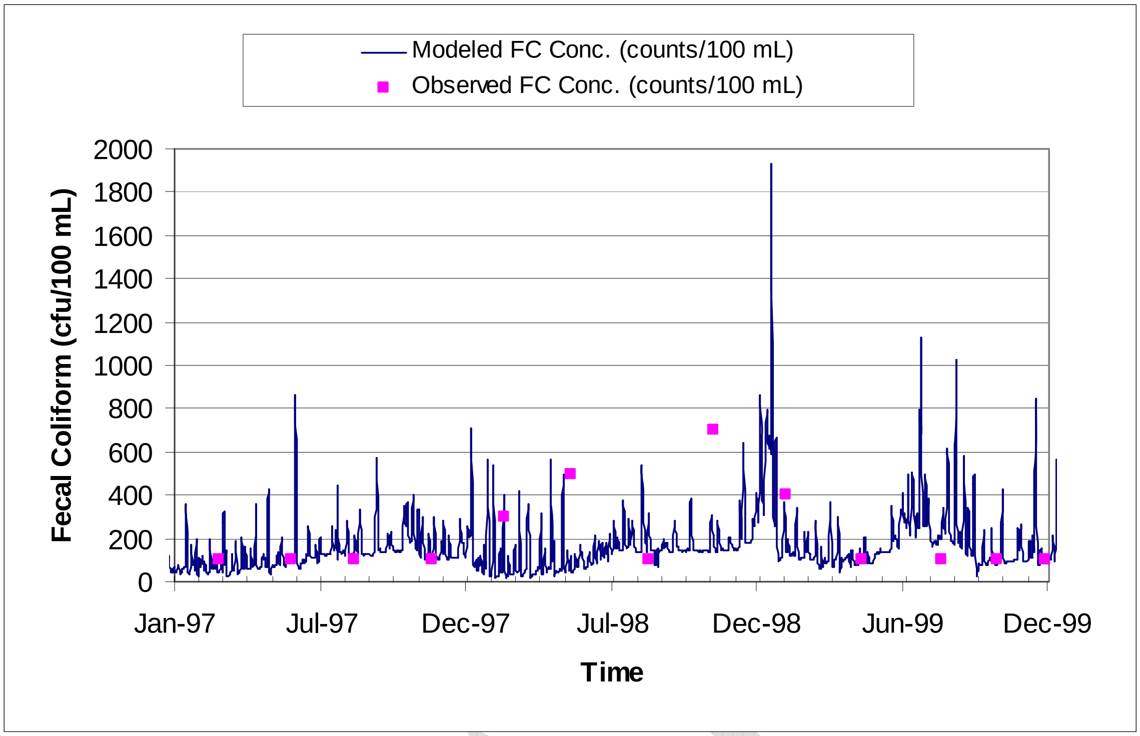


Figure 4-17: Fecal Coliform Calibration Staunton River (Reach 49)

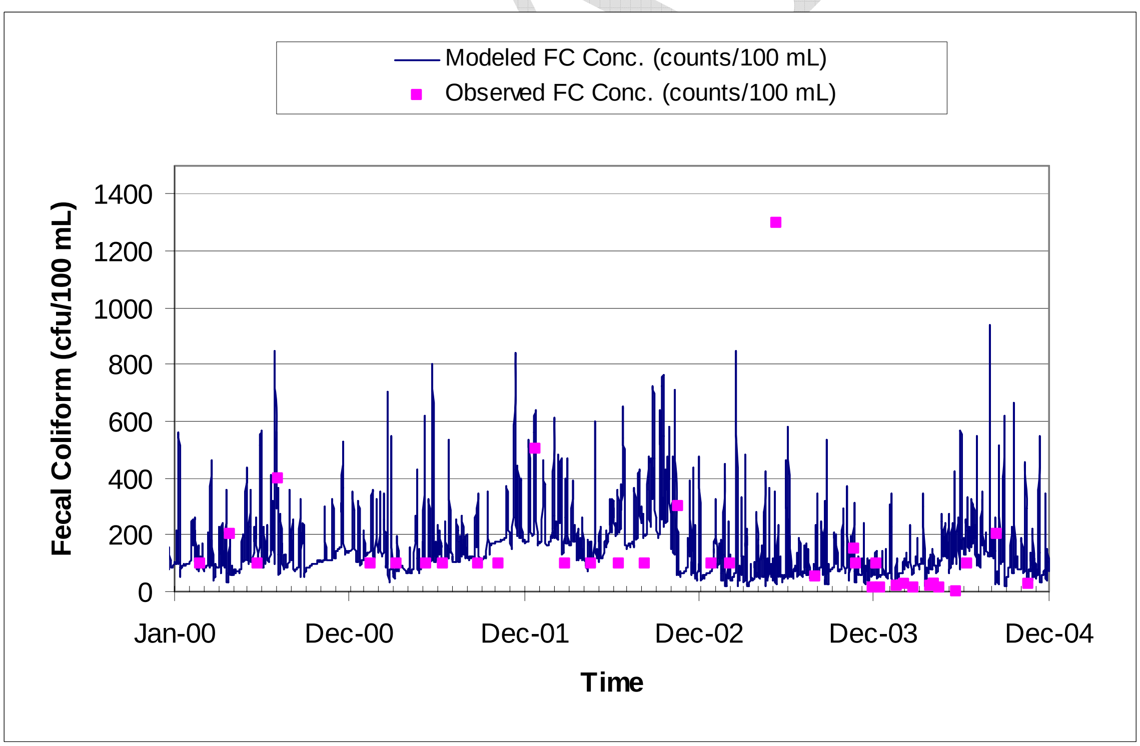


Figure 4-18: Fecal Coliform Validation Staunton River (Reach 49)

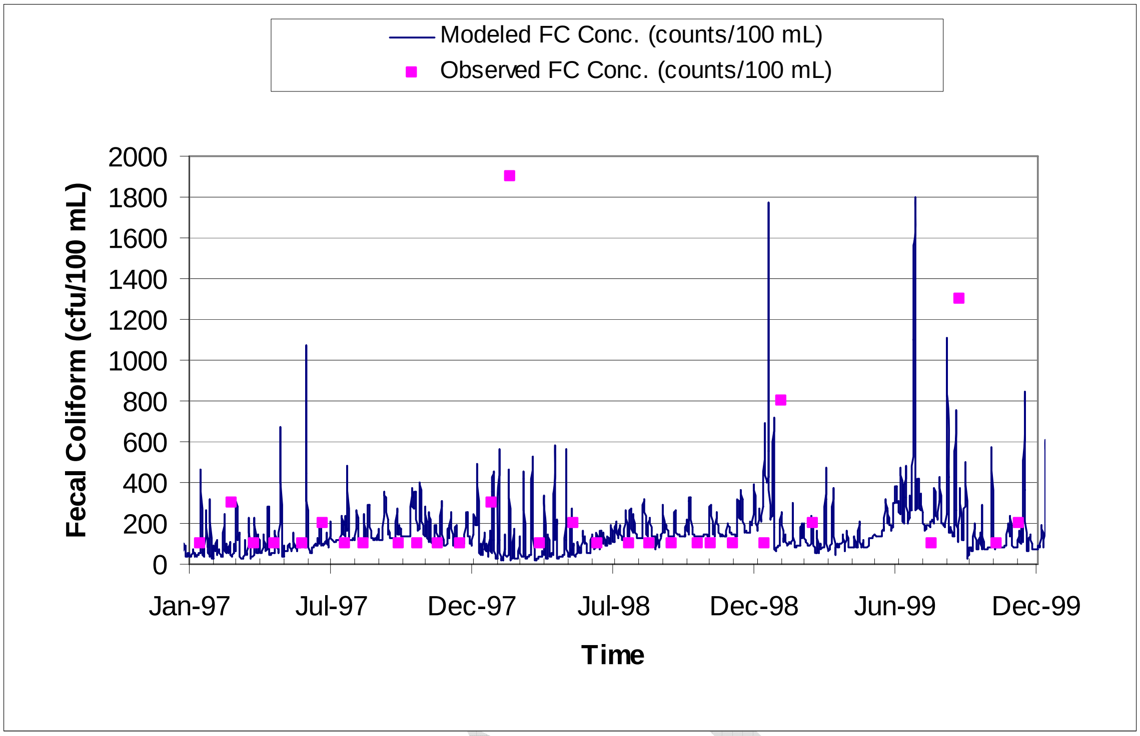


Figure 4-19: Fecal Coliform Calibration Staunton River (Reach 41)

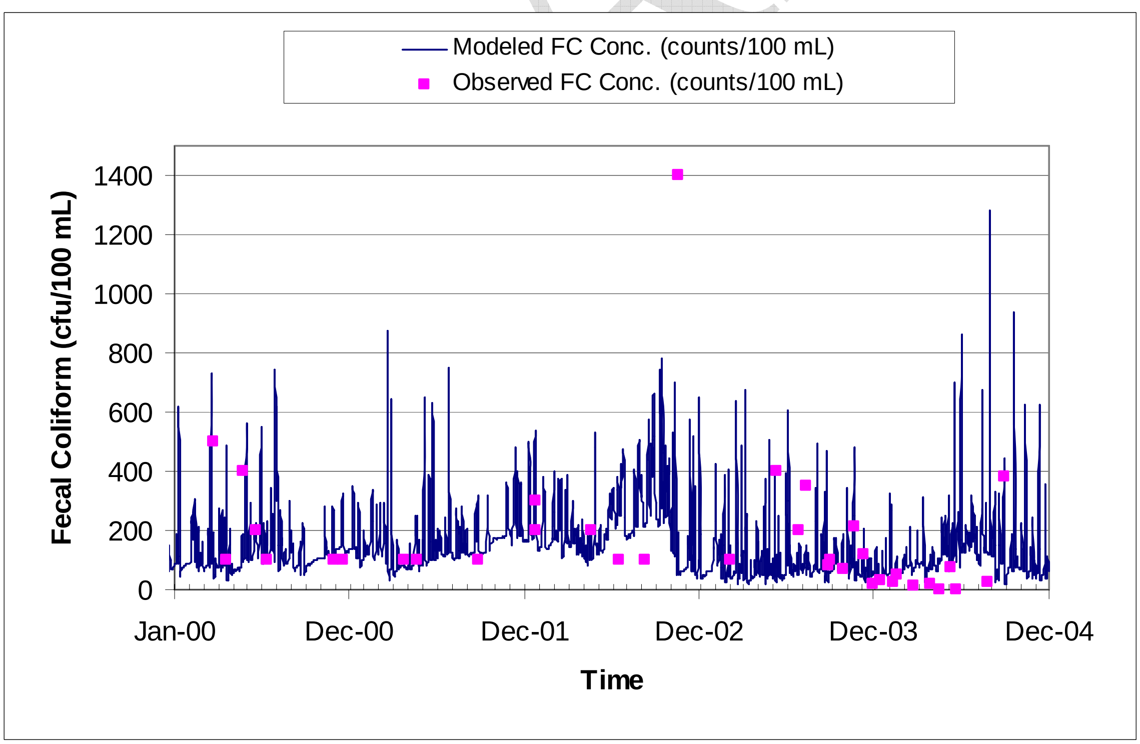


Figure 4-20: Fecal Coliform Validation Staunton River (Reach 41)

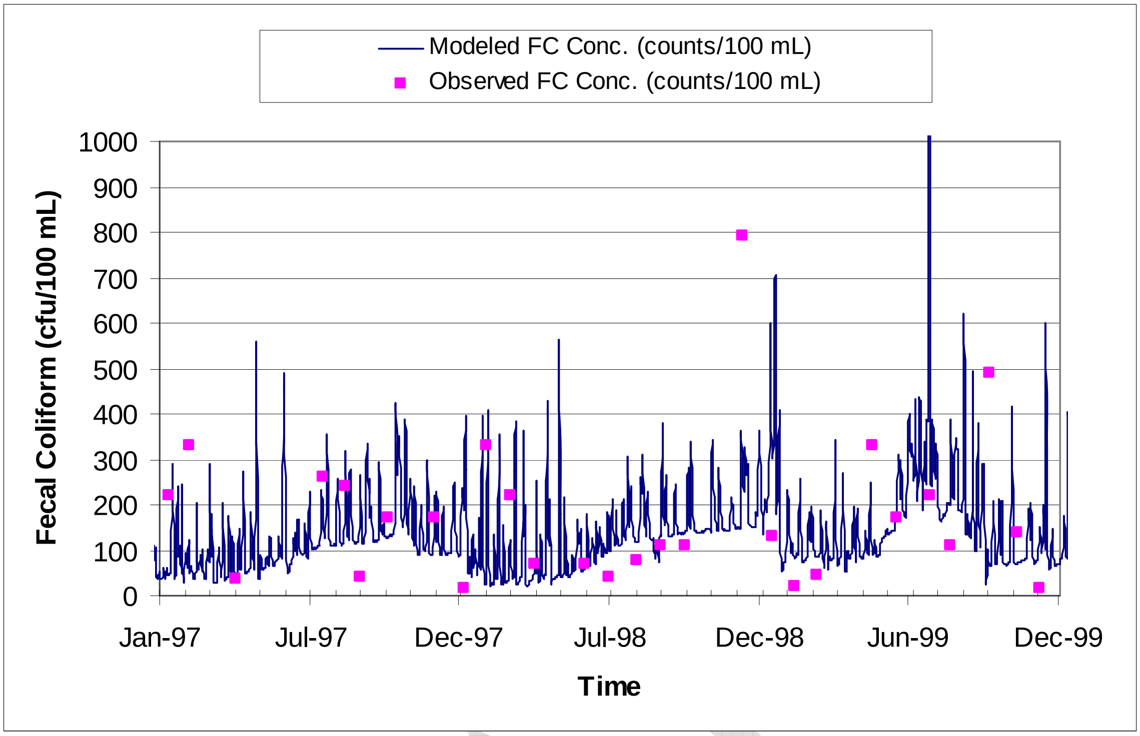


Figure 4-21: Fecal Coliform Calibration Staunton River (Reach 6)

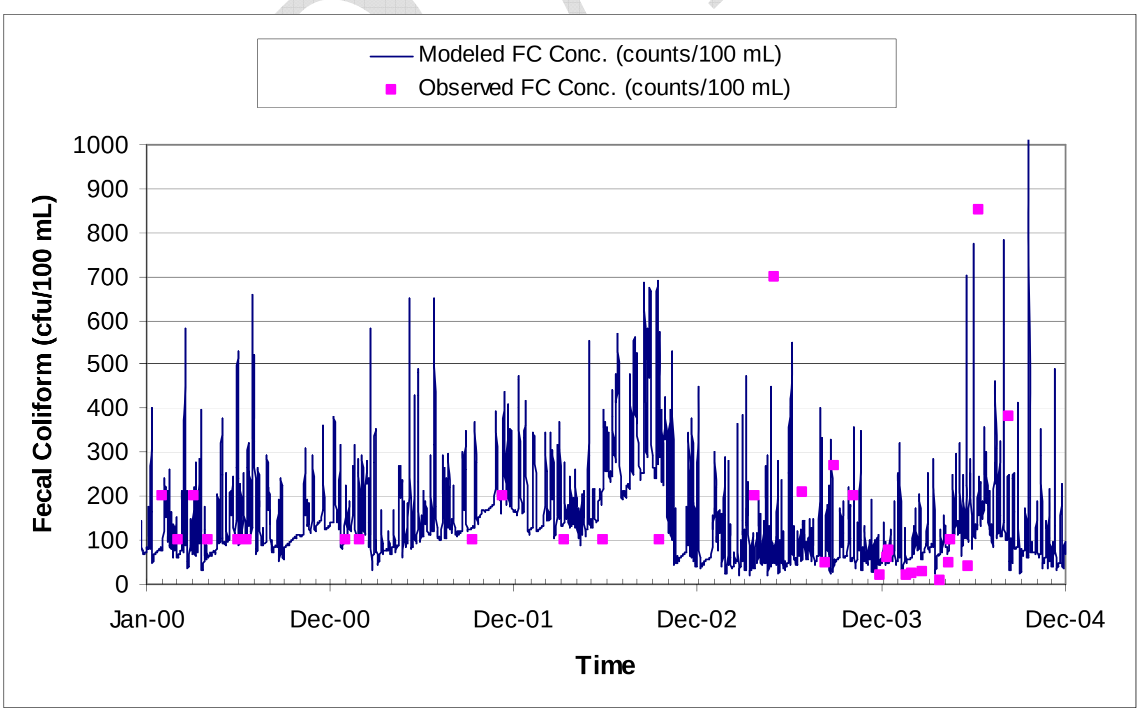


Figure 4-22: Fecal Coliform Validation Staunton River (Reach 6)

4.10 Existing Bacteria Loading

The existing fecal coliform loading for each watershed was calculated based on current watershed conditions. Model input parameters reflected conditions during the period of 1995 to 2004. The standards used for fecal coliform concentrations were a geometric mean standard of 200 cfu/100 ml and an instantaneous standard of 400 cfu/100 ml. For E. coli concentrations, the standards used were a geometric mean of 126 cfu/100ml and an instantaneous standard of 235 cfu/100ml. The E. coli concentrations in the impaired Staunton River (Reach 6), Turnip Creek (Reach 36), Cub Creek (Reach 30), and Buffalo Creek (UT) (Reach 4) were calculated from fecal coliform concentrations using a regression based instream translator, which is presented below:

$$E.\ coli\ concentration\ (cfu/100\ ml) = 2^{-0.0172} \times (FC\ concentration\ (cfu/100ml))^{0.91905}$$

4.10.1 Cub Creek

The instream concentration of bacteria under existing conditions in Cub Creek is above both the fecal coliform and E. coli geometric mean and instantaneous standards for the majority of the time period. **Figure 4-23** shows the fecal coliform geometric mean existing conditions and **Figure 4-24** shows the E. coli geometric mean concentrations under existing conditions. **Figure 4-25** shows the fecal coliform instantaneous concentrations under existing conditions and **Figure 4-26** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing fecal coliform load by source in Cub Creek is presented in **Table 4-21**. The corresponding E. coli loading is presented in **Table 4-22**. E. coli concentrations in the impaired Cub Creek (Reach 30) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-21** and **Table 4-22** show that loading from low density residential areas, wildlife, and pasture areas are the predominant sources of bacteria in the Cub Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from wildlife will dominate. Under wet weather conditions, the non-point source loads from low-density residential and pasture areas will dominate. It should be noted that the point sources' existing-conditions bacteria loads is zero in Tables 4-21 and 4-22 since existing fecal coliform concentration were insignificant.

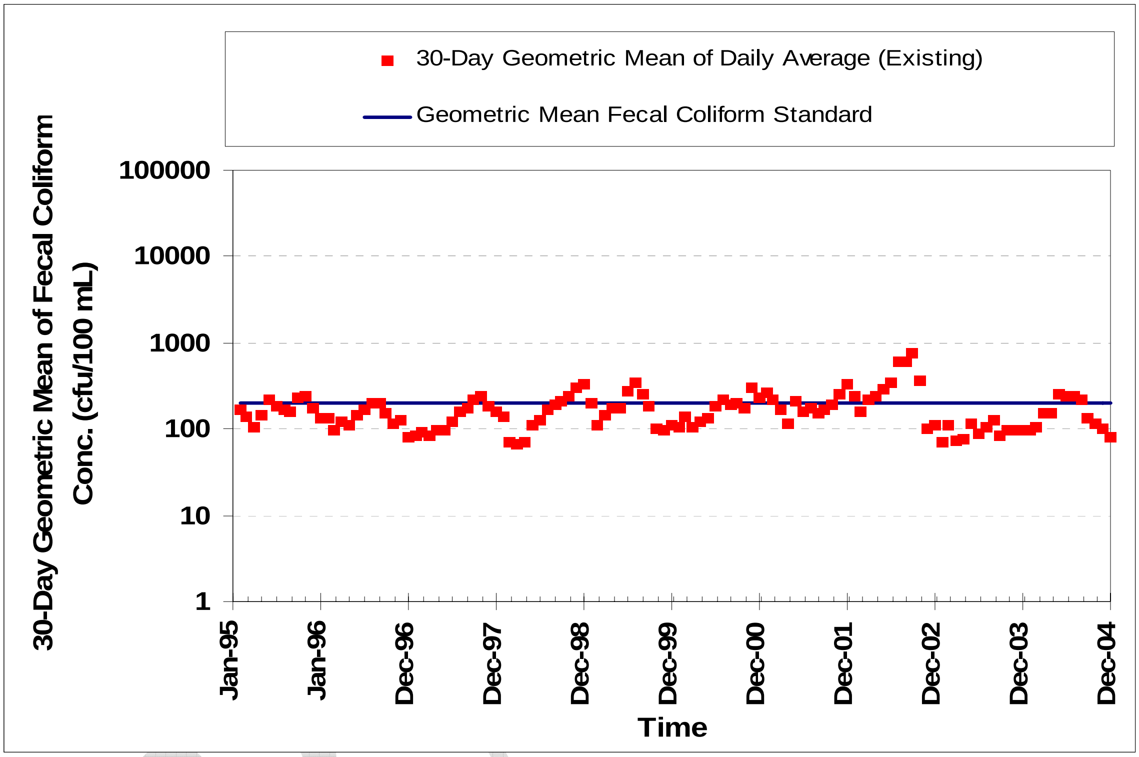


Figure 4-23: Cub Creek Fecal Coliform Geometric Mean Existing Conditions

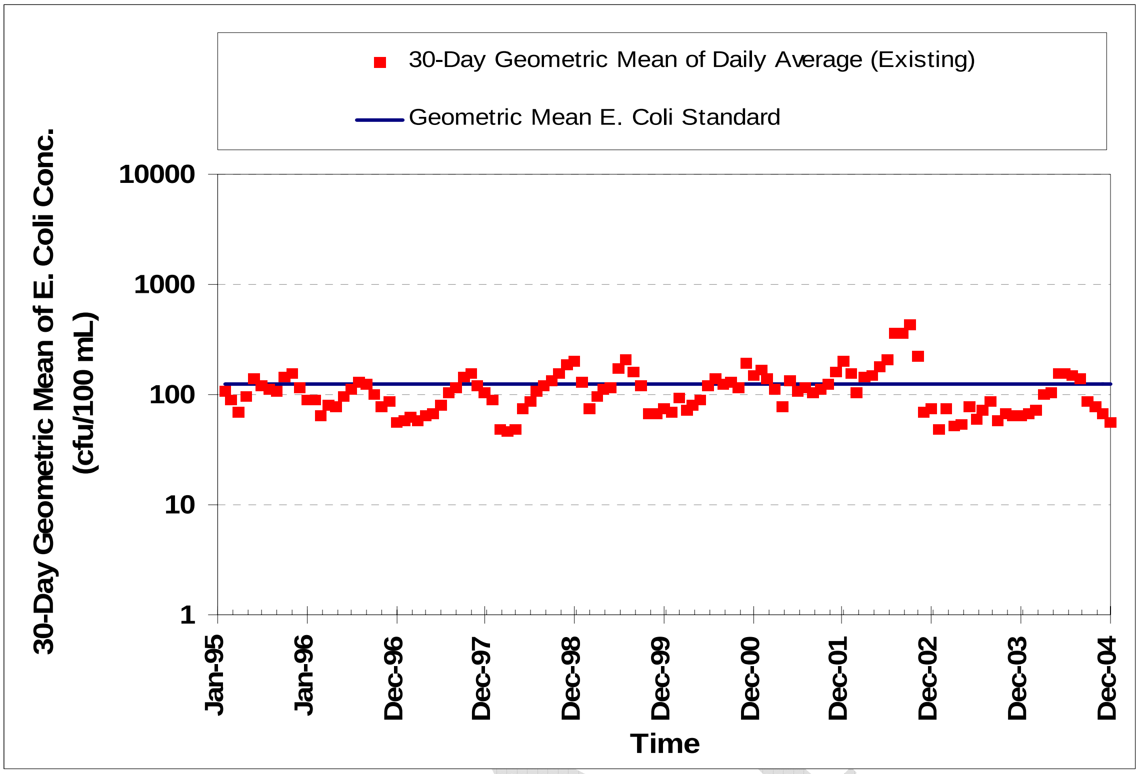


Figure 4-24: Cub Creek E. Coli Geometric Mean Existing Conditions

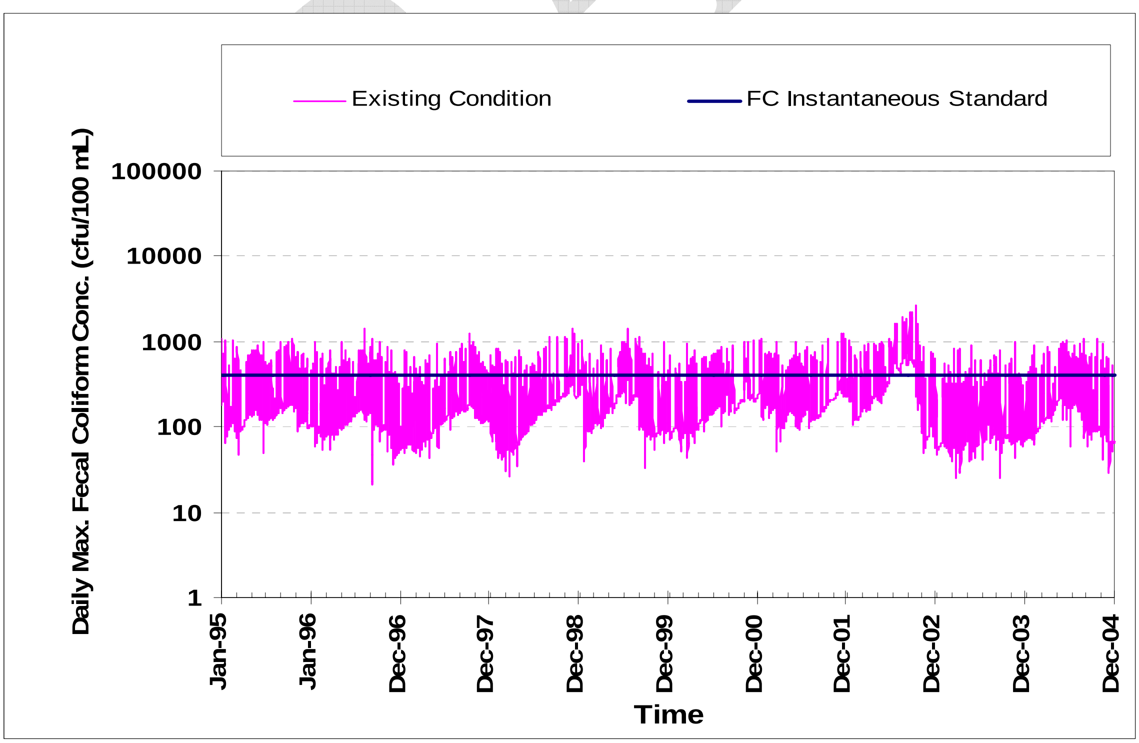


Figure 4-25: Cub Creek Fecal Coliform Instantaneous Existing Conditions

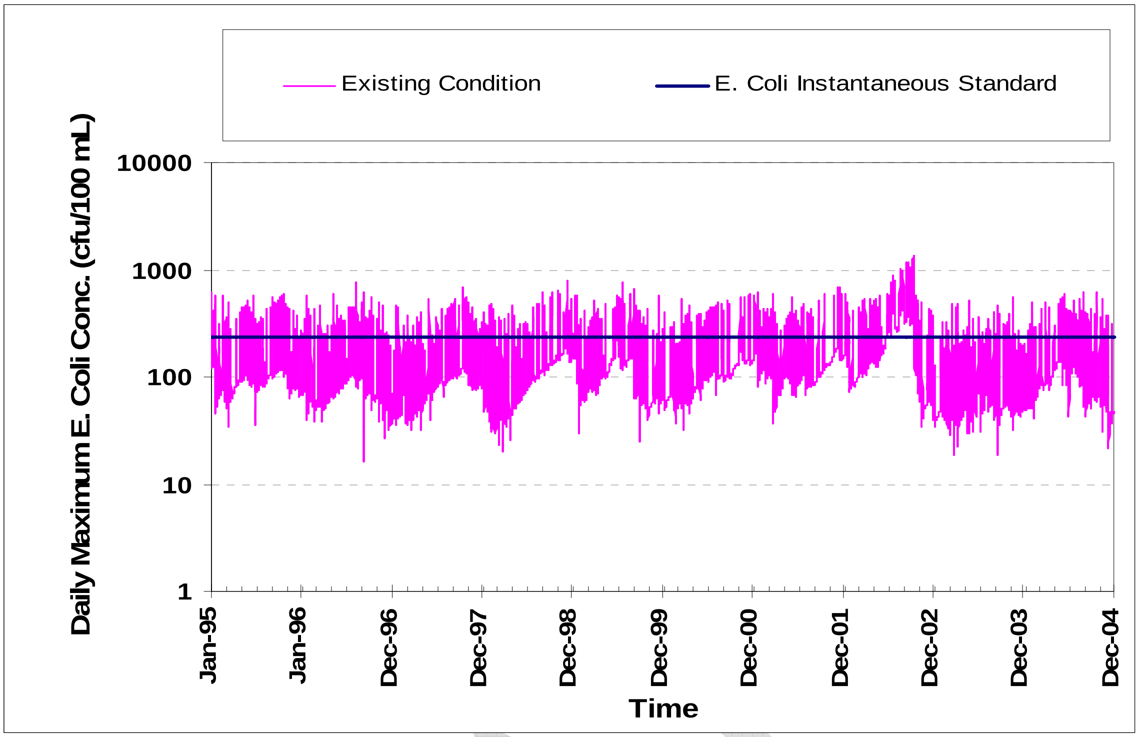


Figure 4-26: Cub Creek E. coli Instantaneous Existing Conditions

Table 4-21: Cub Creek Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	7.53E+12	3.6%
Cropland	6.77E+12	3.3%
Pasture	4.35E+13	21.0%
Low Density Residential	8.04E+13	38.7%
Commercial/Industrial	1.27E+11	0.1%
Water/Wetland	7.39E+10	0.0%
High Density Residential	2.36E+11	0.1%
Failed Septic - direct deposition	5.47E+12	2.6%
Wildlife - direct deposition	4.12E+13	19.8%
Cattle - direct deposition	2.23E+13	10.7%
Point Source	0.00E+00	0.0%
Total	**2.08E+14**	**100%**

Table 4-22: Cub Creek E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent (%)
Forest	6.75E+11	4.2%
Cropland	6.12E+11	3.8%
Pasture	3.39E+12	20.9%
Low Density Residential	5.95E+12	36.7%
Commercial/Indu	1.59E+10	0.1%
Water/Wetland	9.63E+09	0.1%
High Density Residential	2.80E+10	0.2%
Failed Septic - direct deposition	5.04E+11	3.1%
Wildlife - direct deposition	3.22E+12	19.8%
Cattle - direct deposition	1.83E+12	11.3%
Point Source	0.00E+00	0.0%
Total	**1.62E+13**	**100%**

4.10.2 Turnip Creek

The instream concentration of bacteria under existing conditions in Turnip Creek is above both the fecal coliform and E. coli geometric mean and instantaneous standards for the majority of the time period. **Figure 4-27** shows the fecal coliform geometric mean existing conditions and **Figure 4-28** shows the E. coli geometric mean concentrations under existing conditions. **Figure 4-29** shows the fecal coliform instantaneous concentrations under existing conditions and **Figure 4-30** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing fecal coliform load by source in Turnip Creek is presented in **Table 4-23**. The corresponding E. coli loading is presented in **Table 4-24**. E. coli concentrations in the impaired Turnip Creek (Reach 36) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-23** and **Table 4-24** show that loading from pasture land, wildlife, and low density residential areas are the predominant sources of bacteria in the Turnip Creek watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from wildlife will dominate. Under wet weather conditions, the non-point source loads from low-density residential and pasture areas will dominate. It should be noted that the point sources' existing-conditions bacteria loads is zero in Tables 4-23 and 4-24 since existing fecal coliform concentration were insignificant.

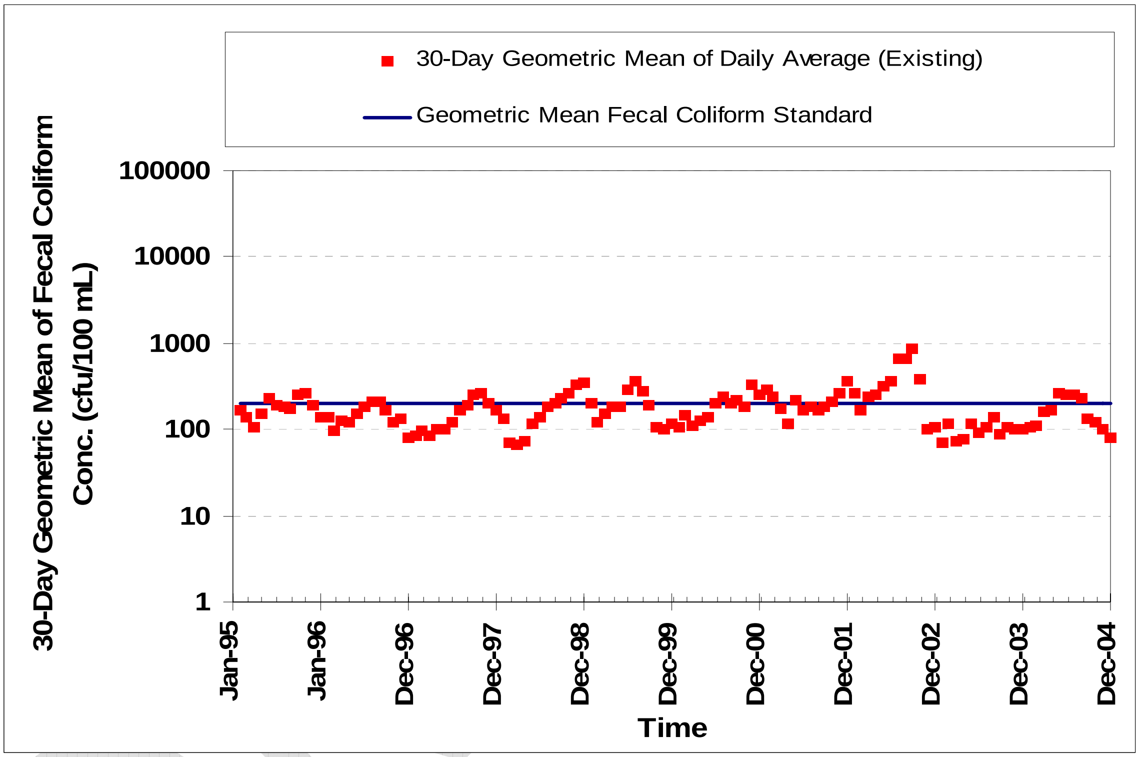


Figure 4-27: Turnip Creek Fecal Coliform Geometric Mean Existing Conditions

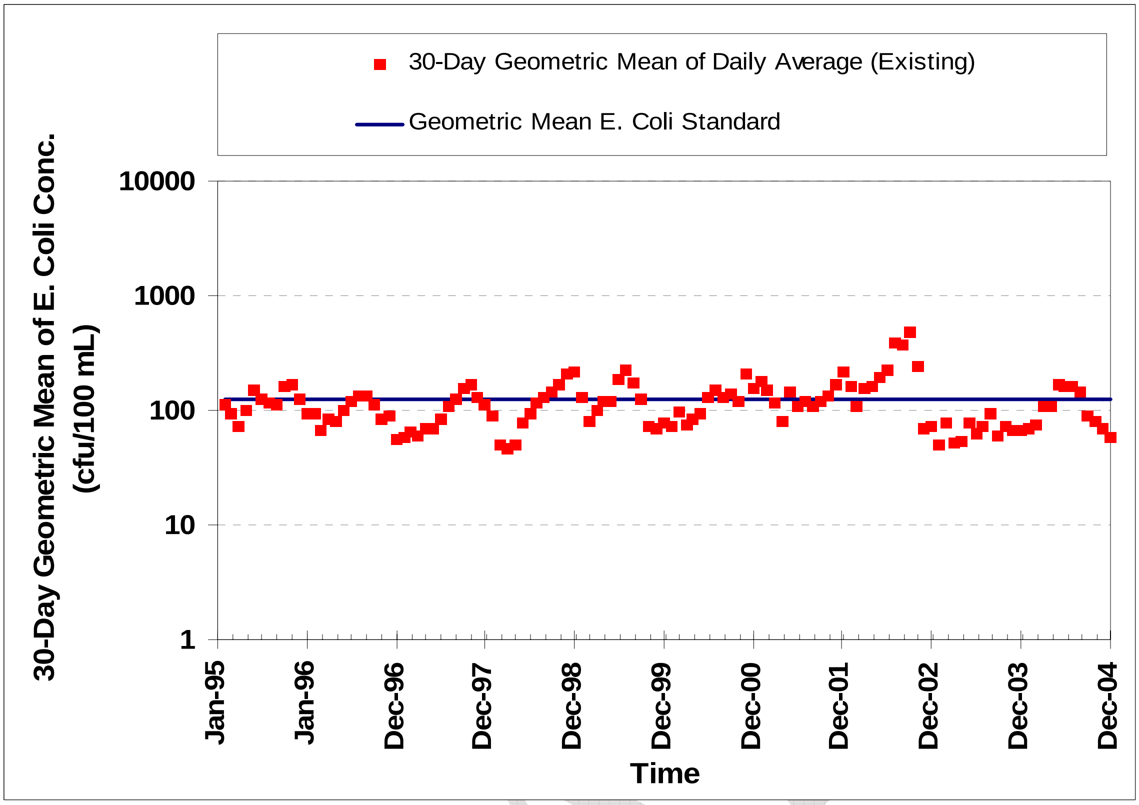


Figure 4-28: Turnip Creek E. Coli Geometric Mean Existing Conditions

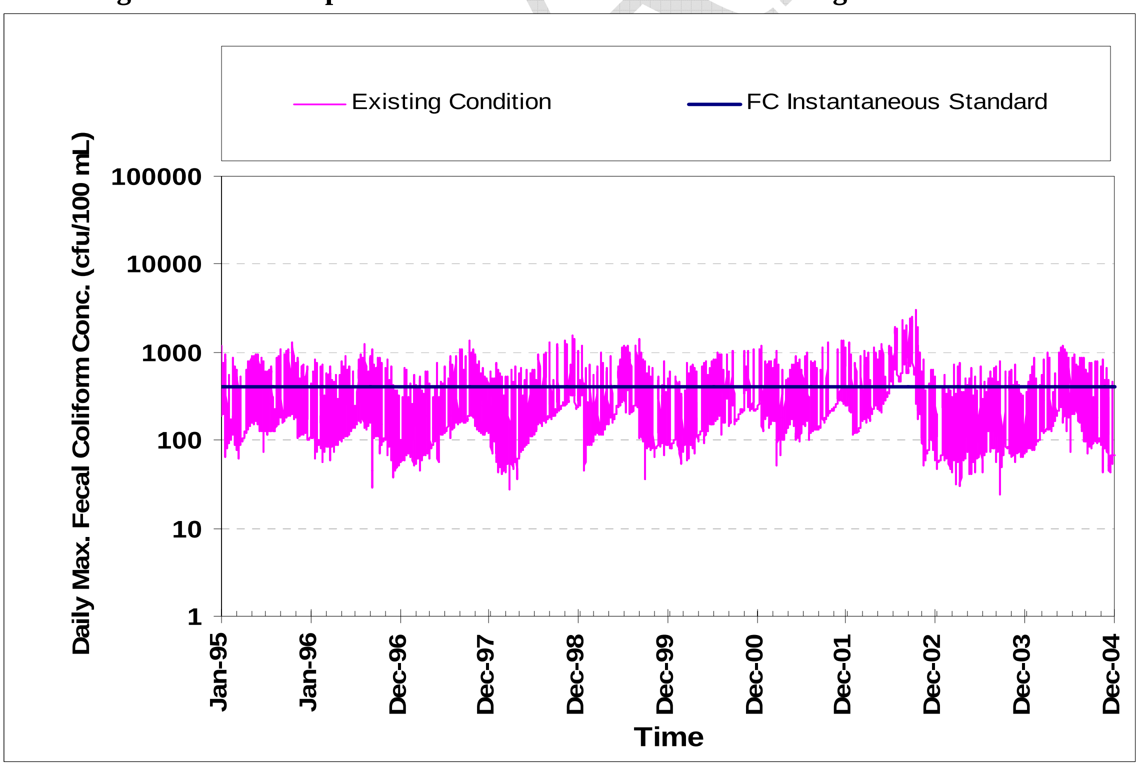


Figure 4-29: Turnip Creek Fecal Coliform Instantaneous Existing Conditions

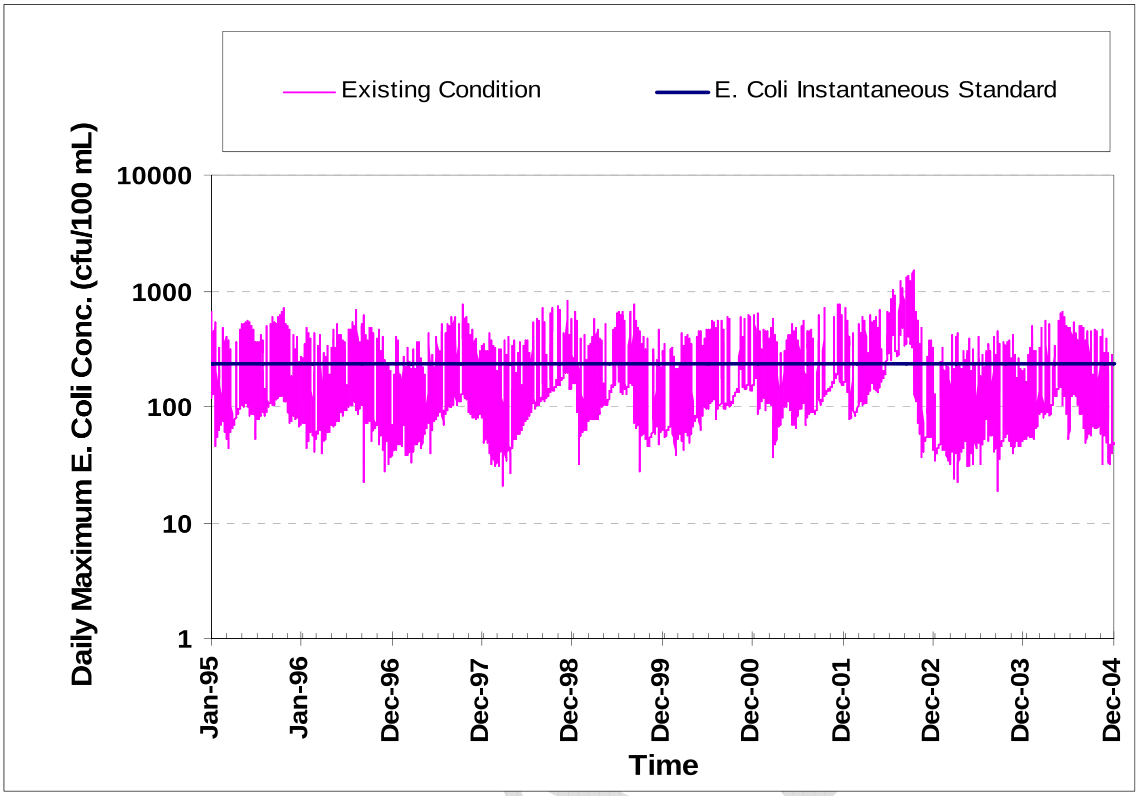


Figure 4-30: Turnip Creek E. coli Instantaneous Existing Conditions

Table 4-23: Turnip Creek Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	2.43E+12	4.1%
Cropland	3.69E+12	6.3%
Pasture	1.60E+13	27.2%
Low	1.27E+13	21.5%
Commercial/Industrial	5.72E+09	0.0%
Water/Wetland	2.92E+10	0.0%
Failed Septic - direct deposition	2.72E+12	4.6%
Wildlife - direct deposition	1.40E+13	23.7%
Cattle - direct deposition	7.42E+12	12.6%
Point Source	0.00E+00	0.0%
Total	**5.89E+13**	**100%**

Table 4-24: Turnip Creek E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent (%)
Forest	2.39E+11	4.6%
Cropland	3.50E+11	6.8%
Pasture	1.35E+12	26.2%
Low	1.09E+12	21.1%
Commercial/Industrial	9.17E+08	0.0%
Water/Wetland	4.10E+09	0.1%
Failed Septic - direct deposition	2.64E+11	5.1%
Wildlife - direct deposition	1.19E+12	23.1%
Cattle - direct deposition	6.66E+11	12.9%
Point Source	0.00E+00	0.0%
Total	**5.15E+12**	**100%**

4.10.3 Buffalo Creek (UT)

The instream concentration of bacteria under existing conditions in Buffalo Creek (UT) is above both the fecal coliform and E. coli geometric mean and instantaneous standards for the majority of the time period. **Figure 4-31** shows the fecal coliform geometric mean existing conditions and **Figure 4-32** shows the E. coli geometric mean concentrations under existing conditions. **Figure 4-33** shows the fecal coliform instantaneous concentrations under existing conditions and **Figure 4-34** shows the E. coli instantaneous concentrations under existing conditions.

Distribution of the existing fecal coliform load by source in Buffalo Creek (UT) is presented in **Table 4-25**. The corresponding E. coli loading is presented in **Table 4-26**. E. coli concentrations in the impaired Buffalo Creek (UT) (Reach 4) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-25** and **Table 4-26** show that loading from the pasture, wildlife and cropland are the predominant sources of bacteria in the Buffalo Creek (UT) watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from wildlife will dominate. Under wet weather conditions, the non-point source loads from and pasture and cropland areas will dominate. It should be noted that the point sources' existing-conditions bacteria loads is zero in Tables 4-23 and 4-24 since there are no point sources dischargers in Buffalo Creek..

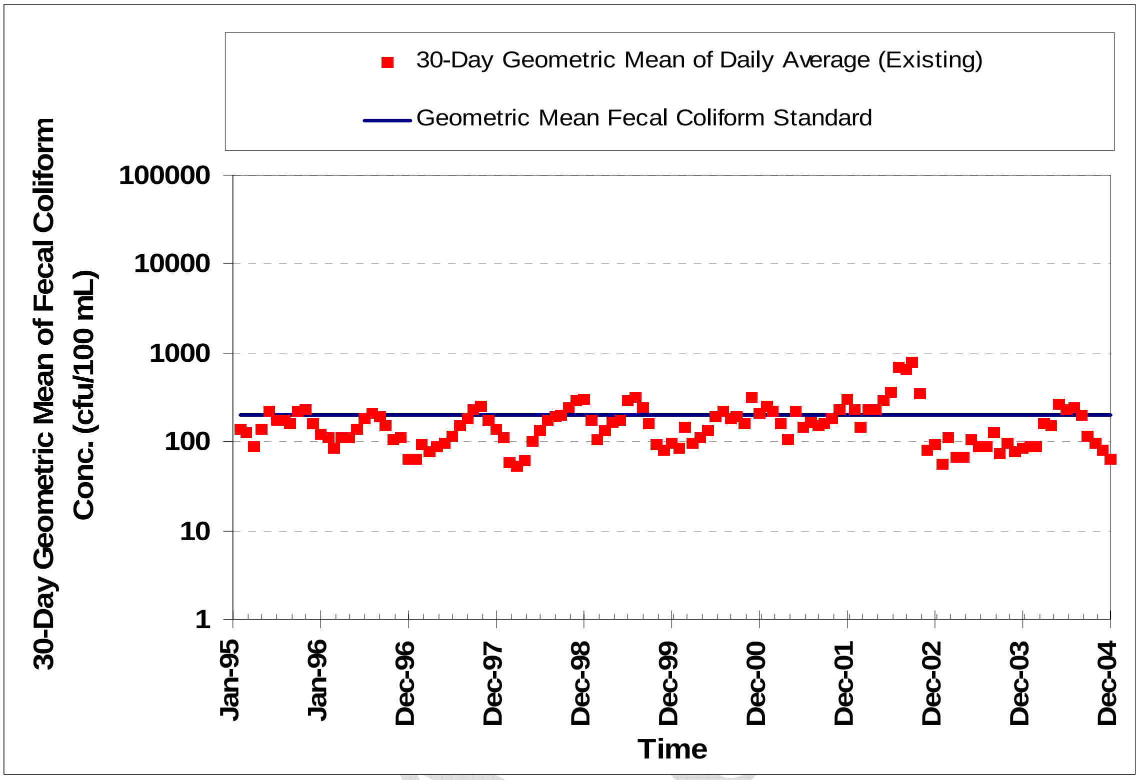


Figure 4-31: Buffalo Creek (UT) Fecal Coliform Geometric Mean Existing Conditions

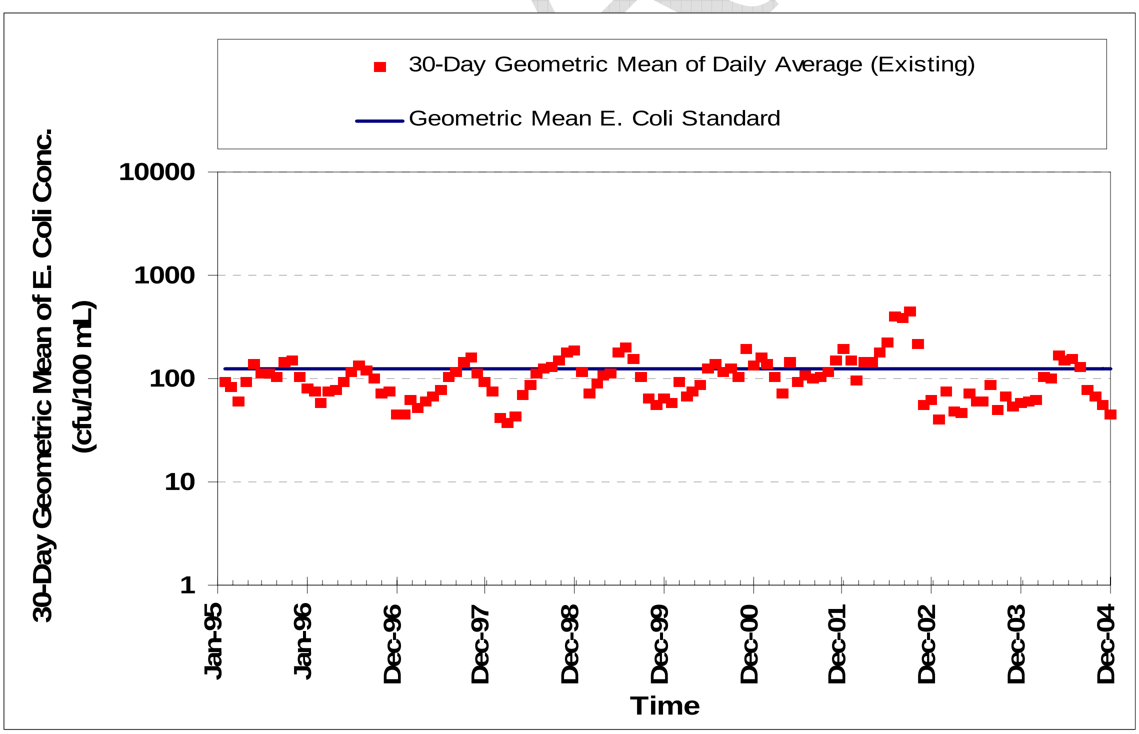


Figure 4-32: Buffalo Creek (UT) E. Coli Geometric Mean Existing Conditions

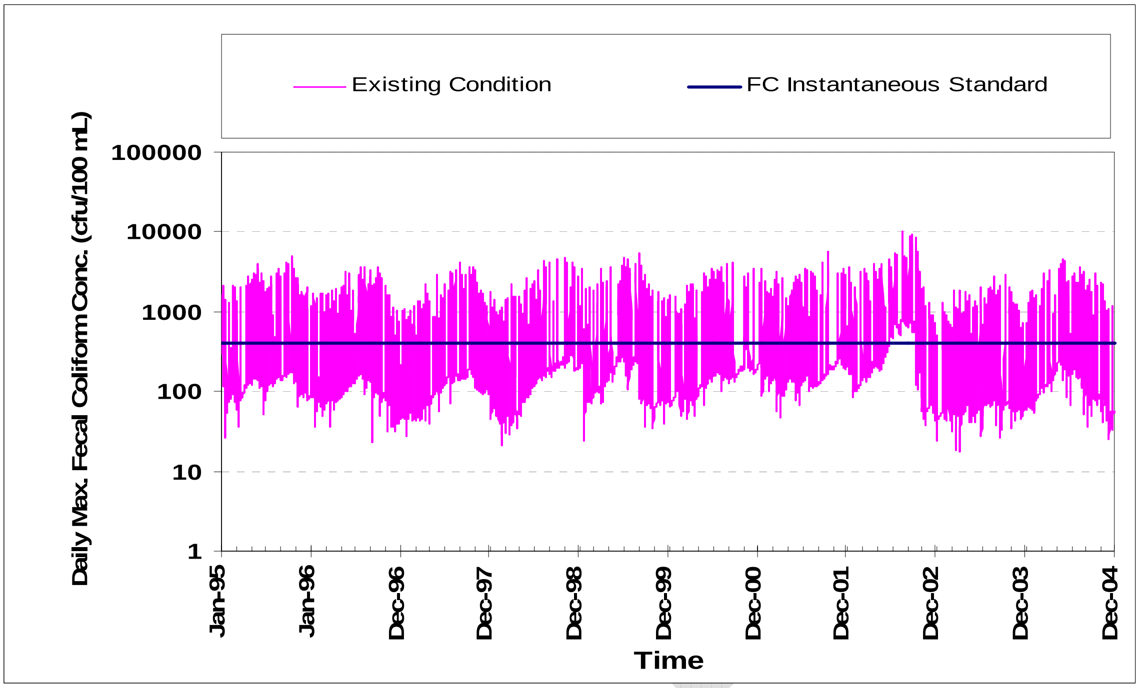


Figure 4-33: Buffalo Creek (UT) Fecal Coliform Instantaneous Existing Conditions

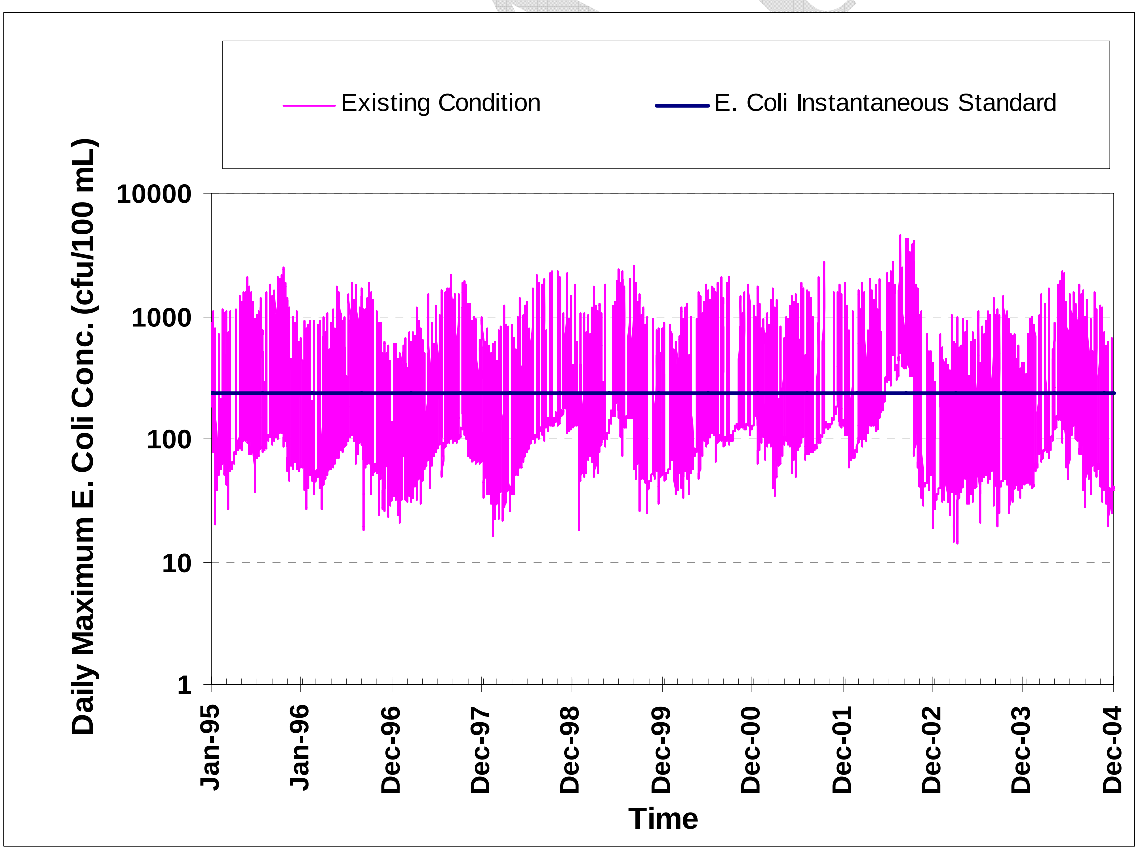


Figure 4-34: Buffalo Creek (UT) E. coli Instantaneous Existing Conditions

Table 4-25: Buffalo Creek (UT) Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	7.60E+10	5.1%
Cropland	2.47E+11	16.6%
Pasture	7.53E+11	50.5%
High Density Residential	4.13E+08	0.0%
Failed Septic - direct deposition	0.00E+00	0.0%
Wildlife - direct deposition	4.14E+11	27.8%
Cattle - direct deposition	0.00E+00	0.0%
Point Source	0.00E+00	0.0%
Total	**1.49E+12**	**100%**

Table 4-26: Buffalo Creek (UT) E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent (%)
Forest	9.88E+09	5.9%
Cropland	2.92E+10	17.4%
Pasture	8.13E+10	48.5%
High Density Residential	8.19E+07	0.0%
Failed Septic - direct deposition	0.00E+00	0.0%
Wildlife - direct deposition	4.70E+10	28.1%
Cattle - direct deposition	0.00E+00	0.0%
Point Source	0.00E+00	0.0%
Total	**1.67E+11**	**100%**

4.10.4 Staunton River

The instream concentration of bacteria under existing conditions in the Staunton River is above both the fecal coliform and E. coli geometric mean and instantaneous standards for the majority of the time period. **Figure 4-35** shows the fecal coliform geometric mean existing conditions and **Figure 4-36** shows the E. coli geometric mean concentrations under existing conditions. **Figure 4-37** shows the fecal coliform instantaneous concentrations under existing conditions and **Figure 4-38** shows the E. coli instantaneous concentrations under existing conditions. Distribution of the existing fecal coliform load by source in Staunton River is presented in **Table 4-27.** The corresponding E. coli loading is presented in **Table 4-28**. E. coli concentrations in the impaired Staunton River (Reach 6) segment were calculated from fecal coliform concentrations using the instream translator. **Table 4-27** and **Table 4-28** show that loading from low density residential, wildlife, pasture, and failed septic systems are the predominant sources of bacteria in the Staunton River watershed. However, both wet weather and dry weather conditions were identified as the critical condition. Under dry weather conditions, the direct deposition load from wildlife, failed septic systems, and straight pipes will dominate. Under wet weather conditions, the non-point source loads from low-density residential and pasture areas will dominate.

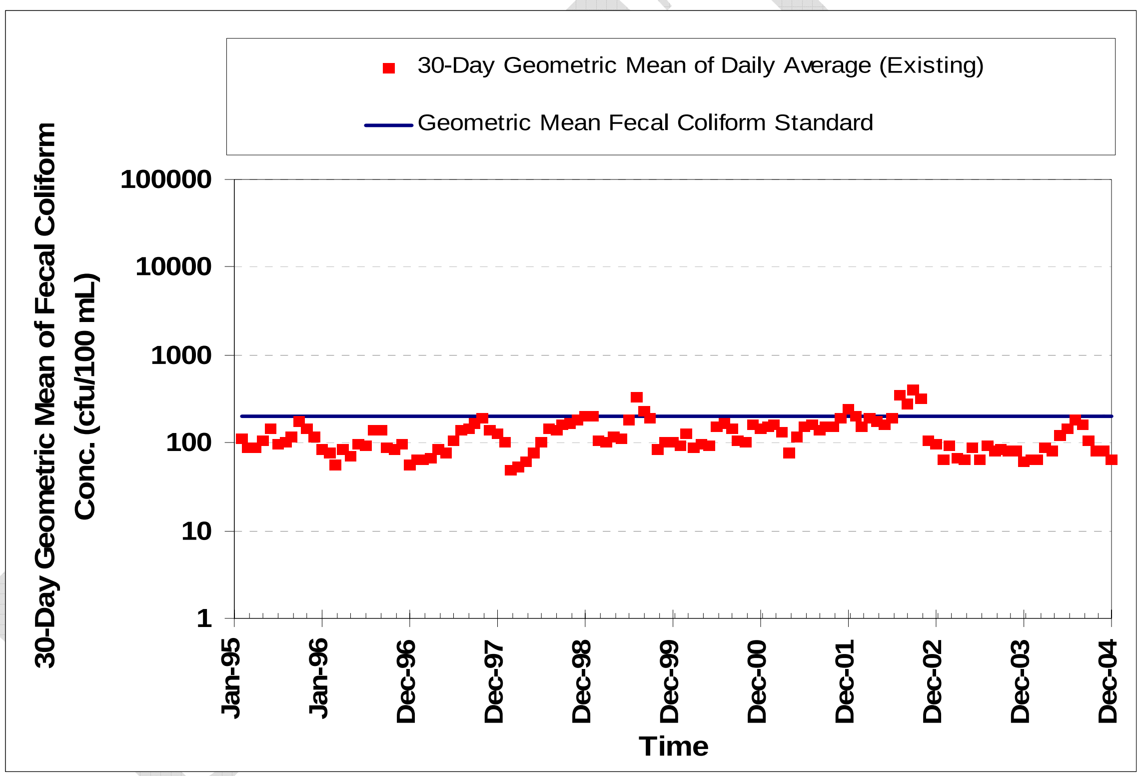


Figure 4-35: Staunton River Fecal Coliform Geometric Mean Existing Conditions

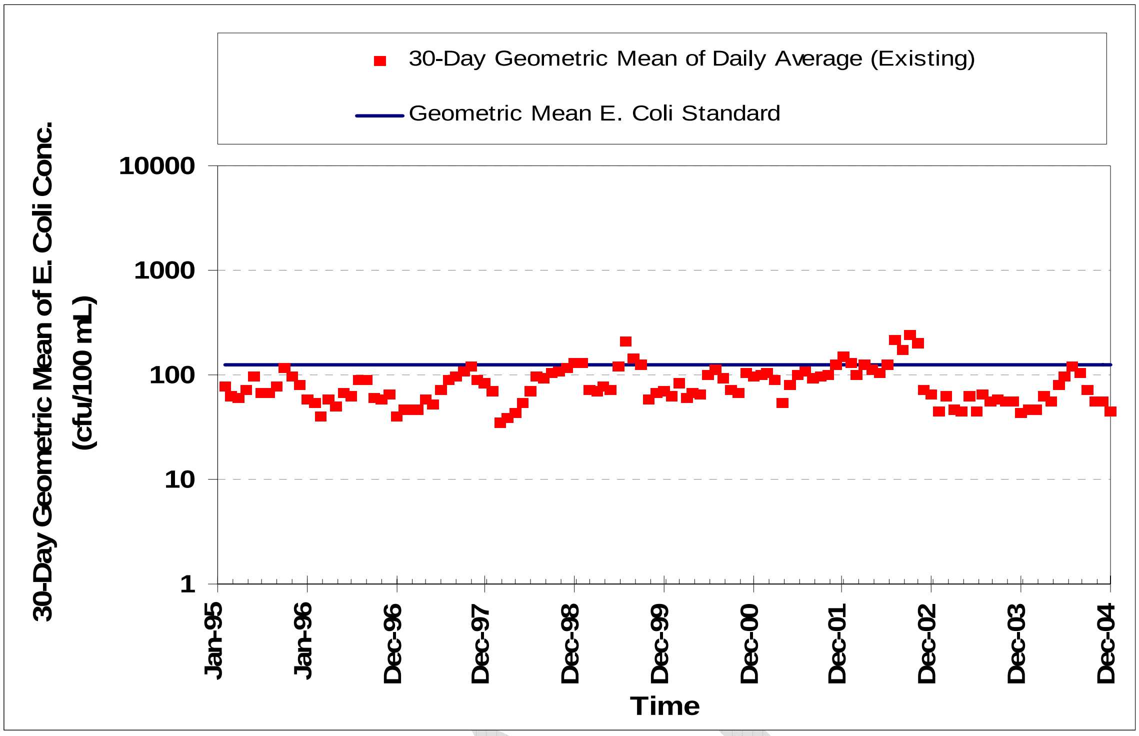


Figure 4-36: Staunton River E. Coli Geometric Mean Existing Conditions

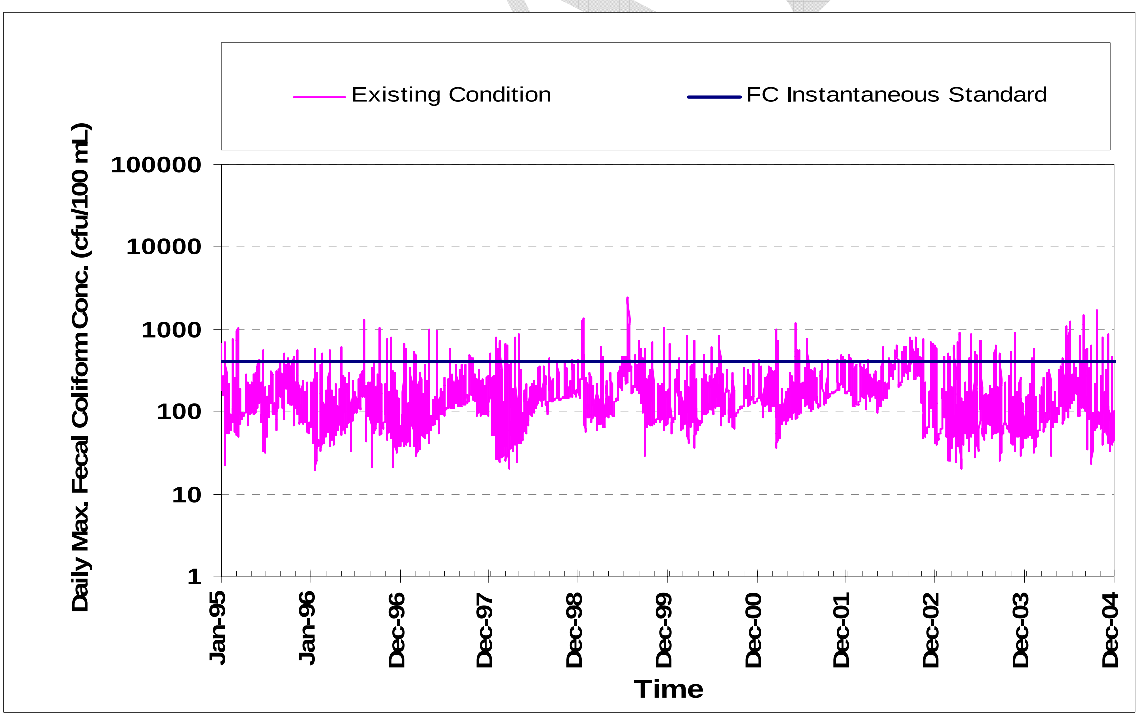


Figure 4-37: Staunton River Fecal Coliform Instantaneous Existing Conditions

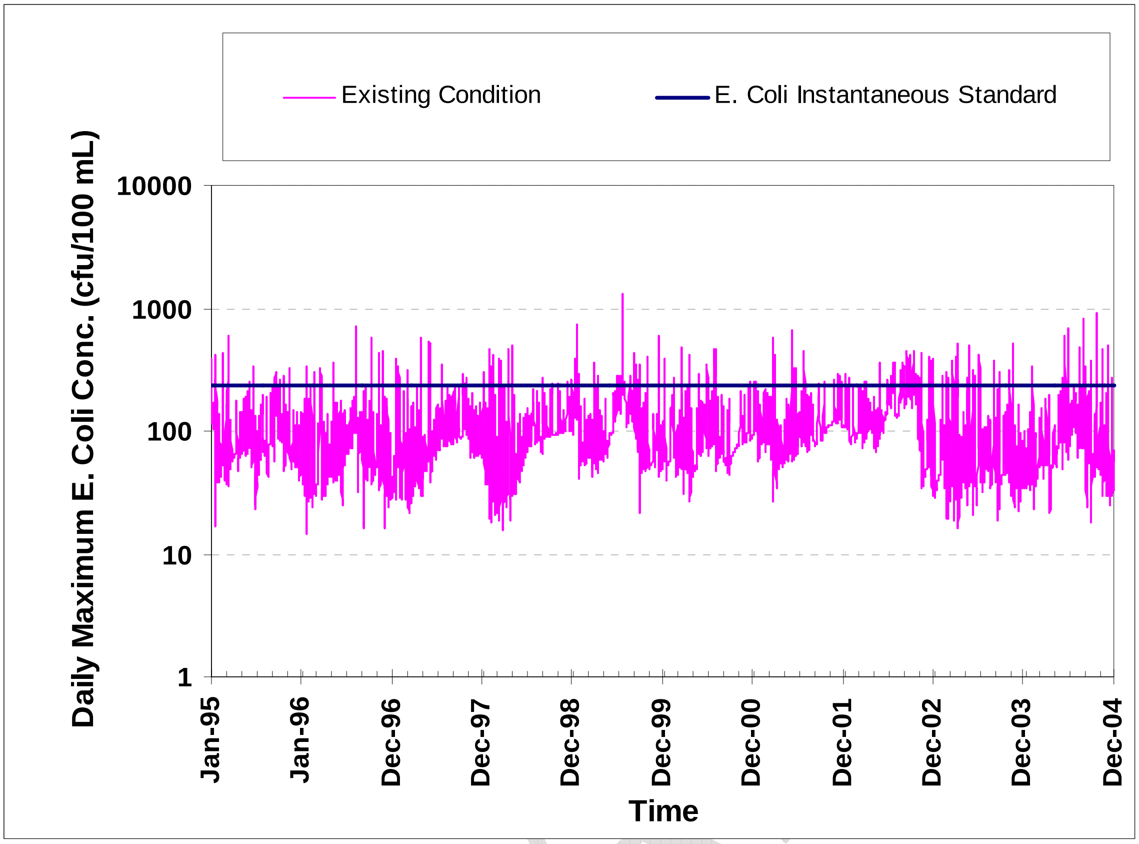


Figure 4-38: Staunton River E. coli Instantaneous Existing Conditions

Table 4-27: Staunton River Fecal Coliform Existing Load Distribution by Source

Source	Annual Average Fecal Coliform Loads	
	cfu/year	Percent (%)
Forest	1.08E+14	2.6%
Cropland	1.50E+14	3.6%
Pasture	7.09E+14	17.2%
Low Density Residential	1.86E+15	45.1%
Commercial/Industrial	7.23E+12	0.2%
Water/Wetland	9.74E+11	0.0%
High Density Residential	2.05E+12	0.0%
Other	0.00E+00	0.0%
Failed Septic - direct deposition	4.00E+14	9.7%
Wildlife - direct deposition	6.28E+14	15.2%
Cattle - direct deposition	2.63E+14	6.4%
Point Source	3.49E+11	0.0%
Total	**4.13E+15**	**100%**

Table 4-28: Staunton River E. coli Existing Load Distribution by Source

Source	Annual Average E. coli Loads	
	cfu/year	Percent (%)
Forest	7.79E+12	3.1%
Cropland	1.05E+13	4.2%
Pasture	4.40E+13	17.4%
Low Density Residential	1.07E+14	42.2%
Commercial/Industrial	6.50E+11	0.3%
Water/Wetland	1.03E+11	0.0%
High Density Residential	2.05E+11	0.1%
Other	0.00E+00	0.0%
Failed Septic - direct deposition	2.60E+13	10.3%
Wildlife - direct deposition	3.93E+13	15.5%
Cattle - direct deposition	1.77E+13	7.0%
Point Source	4.01E+10	0.0%
Total	**2.53E+14**	**100%**

5.0 Allocation

For the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River TMDLs, allocation analysis was the third stage in development. Its purpose was to develop the framework for reducing bacteria loading under the existing watershed conditions so water quality standards can be met. The TMDL represents the maximum amount of pollutant that the stream can receive without exceeding the water quality standard. The load allocations for the selected scenarios were calculated using the following equation:

$$\text{TMDL} = \sum \text{WLA} + \sum \text{LA} + \text{MOS}$$

Where,

WLA = wasteload allocation (point source contributions);

LA = load allocation (non-point source allocation); and

MOS = margin of safety.

Typically, several potential allocation strategies would achieve the TMDL endpoint and water quality standards. Available control options depend on the number, location, and character of pollutant sources.

5.1 Incorporation of Margin of Safety

The margin of safety (MOS) is a required component of the TMDL to account for any lack of knowledge concerning the relationship between effluent limitations and water quality. According to EPA guidance (*Guidance for Water Quality-Based Decisions: The TMDL Process, 1991*), the MOS can be incorporated into the TMDL using two methods:

- Implicitly incorporating the MOS using conservative model assumptions to develop allocations; or
- Explicitly specifying a portion of the TMDL as the MOS and using the remainder for allocations.

The MOS will be implicitly incorporated into this TMDL. Implicitly incorporating the MOS will require that allocation scenarios be designed to meet the monthly fecal coliform geometric mean standard of 200 cfu/100 ml and the instantaneous fecal coliform standard of 400 cfu/100 ml with 0% exceedance. In terms of E. coli, incorporating an implicit MOS will require that the allocation scenario be designed to meet the monthly geometric mean standard of 126 cfu/100 ml and the instantaneous standard of 235 cfu/100 ml with 0 violations.

5.2 Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violations, and provides insight and direction in developing the TMDL allocations and implementation. Based on the sensitivity analysis, several allocation scenarios were developed. For each scenario developed, the percent of days water quality conditions violate the monthly geometric mean standard and instantaneous standard for E. coli were calculated. The results of the sensitivity analysis are presented in Appendix E.

5.3 Allocation Scenario Development

Allocation scenarios were modeled using the calibrated HSPF model to adjust the existing conditions until the water quality standard was attained. The TMDLs developed for the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River were based on the Virginia State Standard for E. coli. As detailed in Section 1.2, the E. coli standard states that the calendar month geometric-mean concentration shall not exceed 126 cfu/100 ml, and that a maximum single sample concentration of E. coli not exceed 235 cfu/100 ml. According to the guidelines put forth by the DEQ (DEQ, 2003) for modeling E. coli with HSPF, the model was set up to estimate loads of fecal coliform, and then the model output was converted to concentrations of E. coli with the following equation:

$$\log_2 (C_{ec}) = -0.0172+0.91905*\log2(c_{fc})$$

Where C_{ec} is the concentration of E. coli in cfu/100 ml, and C_{fc} is the concentration of fecal coliform in cfu/100 ml.

The pollutant concentrations were simulated over the entire duration of a representative modeling period, and pollutant loads were adjusted until the standard was met. The development of the allocation scenarios was an iterative process requiring numerous runs where each run was followed by an assessment of source reduction against the water quality target. The following sections present the waste load allocation (WLA) and load allocations (LA) for the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River.

5.3.1 Wasteload Allocation

5.3.1.1. Cub Creek Wasteload Allocation

There are four facilities discharging bacteria to Cub Creek. They consist of two minor dischargers (schools) and two general-permit dischargers (residences). These facilities do not have a permit limit for bacteria. For this TMDL, the wasteload allocation for such facilities is to maintain discharge at the design flow limits and bacteria concentrations at the existing E-coli standard of 126 cfu/100mL. **Table 5-1** shows the loading from the permitted point source dischargers in Cub Creek.

Table 5-1: Cub Creek Wasteload Allocation for E. coli

Point Source	Existing Load (cfu/day)	Allocated Load (cfu/day)	Percent Reduction
VA0063118	1.91E+07	1.91E+07	0%
VA0029319	2.86E+07	2.86E+07	0%
VA0029335	2.86E+07	2.86E+07	0%
VAG404021	2.14E+06	2.14E+06	0%
Total	7.85E+07	7.85E+07	0%

5.3.1.2. Turnip Creek Waste Load Allocation

There is only one industrial permitted facility currently discharging into Cub Creek. This facility does not have a permit limit for bacteria. For this TMDL, the wasteload allocation for this facility is to maintain discharge at the design flow limits and bacteria concentrations at the existing E-coli standard of 126 cfu/100mL. **Table 5-2** shows the loading from the permitted point source discharger in Turnip Creek.

Table 5-2: Turnip Creek Waste load Allocation for E. coli

Point Source	Existing Load (cfu/day)	Allocated Load (cfu/day)	Percent Reduction
VA0051934	7.14E+06	7.14E+06	0%

5.3.1.3. Buffalo Creek Waste Load Allocation

There are no industrial or municipal permitted facilities currently discharging into Buffalo Creek. Following DEQ guidance, waste load allocations in watersheds without permitted facilities should not be shown as zero. Rather, they should be represented in the TMDL, expressed in terms of "less than" a number equal to or smaller than 1% of the Total Maximum Daily Load. This is reflected in Table 5-14 showing the TMDL allocation plan for Buffalo Creek.

5.3.1.4. Staunton River Waste Load Allocation

There are 27 industrial and municipal permitted facilities in the Staunton River watershed permitted to discharge bacteria (see Chapter 4). For this TMDL, the wasteload allocation for permitted facilities is to maintain discharge at the design flow limits and bacteria concentrations at their permitted levels of 126 cfu/100mL. **Table 5-3** shows the loading from the permitted point source dischargers in the watershed.

Table 5-3: Staunton River Waste load Allocation for E. coli

Point Source	Existing Load (cfu/day)	Allocated Load (cfu/day)	Percent Reduction
VA0020451	1.72E+10	1.72E+10	0%
VA0087106	6.99E+09	6.99E+09	0%
VA0022241	3.72E+08	3.72E+08	0%
VA0001678	1.56E+10	1.56E+10	0%
VA0073733	1.67E+08	1.67E+08	0%
VA0001538	6.32E+09	6.32E+09	0%
VA0083402	4.16E+08	4.16E+08	0%
VA0083399	9.16E+08	9.16E+08	0%
VA0084433	3.82E+08	3.82E+08	0%

Point Source	Existing Load (cfu/day)	Allocated Load (cfu/day)	Percent Reduction
VA0022748	3.43E+07	3.43E+07	0%
VA0024058	1.19E+09	1.19E+09	0%
VA0083097	8.28E+09	8.28E+09	0%
VA0050822	3.85E+08	3.85E+08	0%
VA0087238	9.54E+07	9.54E+07	0%
VA0063738	1.22E+08	1.22E+08	0%
VA0020869	1.67E+07	1.67E+07	0%
VA0089052	4.77E+02	4.77E+02	0%
VA0054577	4.77E+02	4.77E+02	0%
VA0060909	7.15E+07	7.15E+07	0%
VA0051721	8.11E+07	8.11E+07	0%
VA0023515	1.00E+08	1.00E+08	0%
VA0001490	3.10E+08	3.10E+08	0%
VA0026051	2.71E+09	2.71E+09	0%
VA0051446	2.23E+09	2.23E+09	0%
VA0074870	2.29E+07	2.29E+07	0%
VAG404017	4.77E+06	4.77E+06	0%
VAG404081	2.15E+06	2.15E+06	0%
VAG404106	2.15E+06	2.15E+06	0%
VAG404143	2.86E+06	2.86E+06	0%
Total	**6.40E+10**	**6.40E+10**	**0%**

5.3.2 Load Allocation

The reduction of loading from non-point sources, including livestock and wildlife direct deposition, is incorporated into the load allocation. A number of load allocation scenarios were developed in order to determine the final TMDL load allocation. Fecal coliform loading and instream fecal coliform concentrations were estimated for each potential scenario using the HSPF model for the hydrologic period of January 1995 to

December 2004. **Table 5-4** shows the typical load allocation scenarios that were run to arrive at the final TMDL allocations. The following is a brief summary of the key scenarios:

- Scenario 0 is the existing load, no reduction of any of the sources.
- Scenario 1 represents elimination of human sources (septic systems and straight pipes).
- Scenario 3 represents elimination of the human sources (septic systems and straight pipes) as well as the direct instream loading from livestock.
- Scenario 4 represents the direct instream loading from wildlife (all other sources are eliminated).

Table 5-4: Cub Creek, Turnip Creek, Buffalo Creek, and Staunton TMDL Load Allocation Scenarios

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agriculture)	NPS (Urban)	Direct Wildlife
0	0%	0%	0%	0%	0%
1	100%	0%	0%	0%	0%
2	100%	50%	0%	0%	0%
3	100%	100%	0%	0%	0%
4	100%	100%	100%	100%	0%
5	100%	100%	0%	0%	50%
6	100%	100%	0%	0%	75%
7	100%	100%	95%	95%	75%

The estimated load reductions for the Cub Creek, Turnip Creek, Buffalo Creek, and Staunton River from these allocation scenarios are presented separately in the next sections. In addition, the percent of days the 126 cfu/100ml E. coli geometric mean water quality standard and the 235 cfu/100ml E. coli instantaneous water quality standard were violated under each scenario are presented.

5.3.2.1. Cub Creek Load Allocation

The scenarios considered for Cub Creek load allocation are presented in **Table 5-5**. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 9 percent violation of the E. coli geometric mean standard and a 61 percent violation of the E. coli instantaneous standard.
3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 3 percent violation of the E. coli geometric mean standard and a 43 percent violation of the E. coli instantaneous standard.
4. No violations of the E. coli geometric mean standard occurred in Cub Creek under Scenario 9.

Therefore, scenario 9 was chosen as the final TMDL load allocation scenario for Cub Creek. Under this scenario, complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and a 95 percent reduction of urban and agricultural non-point sources, and a 70 percent reduction of direct loading by wildlife are required.

Table 5-5: Cub Creek Load Reductions under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agri-cultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0	0%	0%	0%	0%	0%	31%	100%
1	100%	0%	0%	0%	0%	28%	100%
2	100%	50%	0%	0%	0%	18%	100%
3	100%	100%	0%	0%	0%	9%	61%
4	100%	100%	100%	100%	0%	3%	43%
5	100%	100%	0%	0%	50%	3%	55%
6	100%	100%	0%	0%	75%	2%	52%
7	100%	100%	95%	95%	75%	0%	0%
8	100%	100%	100%	100%	50%	0%	0%
9	100%	100%	95%	95%	70%	0%	0%

5.3.2.2. Turnip Creek Load Allocation

The scenarios considered for Turnip Creek load allocation are presented in **Table 5-6**. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 11 percent violation of the E. coli geometric mean standard and a 70 percent violation of the E. coli instantaneous standard.
3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 5 percent violation of the E. coli geometric mean standard and a 77 percent violation of the E. coli instantaneous standard.
4. No violations of either the E. coli geometric mean standard or the instantaneous E. coli standards occurred in the Turnip Creek under Scenario 9.

Therefore, Scenario 9 was chosen as the final TMDL load allocation scenario for Turnip Creek. Under this scenario, complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and 90 percent reduction of urban and agricultural non-point sources, and a 70 percent reduction of direct loading by wildlife are required.

Table 5-6: Turnip Creek Load Reductions under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0	0%	0%	0%	0%	0%	35%	100%
1	100%	0%	0%	0%	0%	29%	100%
2	100%	50%	0%	0%	0%	22%	100%
3	100%	100%	0%	0%	0%	11%	70%
4	100%	100%	100%	100%	0%	5%	77%
5	100%	100%	0%	0%	50%	4%	58%
6	100%	100%	0%	0%	75%	2%	53%
7	100%	100%	95%	95%	75%	0%	0%
8	100%	100%	100%	100%	50%	0%	0%
9	100%	100%	90%	90%	70%	0%	0%

5.3.2.3. Buffalo Creek Load Allocation

The scenarios considered for Buffalo Creek load allocation are presented in **Table 5-7**. The following conclusions can be made:

5. In Scenario 0 (existing conditions), the water quality standard was violated most of the time.
6. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 8 percent violation of the E. coli geometric mean standard and a 90 percent violation of the E. coli instantaneous standard.
7. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 3 percent violation of the E. coli geometric mean standard and a 63 percent violation of the E. coli instantaneous standard.
8. No violations of either the E. coli geometric mean standard or the instantaneous E. coli standards occurred in the Buffalo Creek under Scenario 9.

Therefore, Scenario 9 was chosen as the final TMDL load allocation scenario for Buffalo Creek. Under this scenario, complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and 90 percent reduction of urban and 98 percent reduction of agricultural non-point sources, and a 70 percent reduction of direct loading by wildlife are required.

Table 5-7: Buffalo Creek Load Reductions under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0	0%	0%	0%	0%	0%	28%	100%
1	100%	0%	0%	0%	0%	28%	100%
2	100%	50%	0%	0%	0%	17%	100%
3	100%	100%	0%	0%	0%	8%	90%
4	100%	100%	100%	100%	0%	3%	63%
5	100%	100%	0%	0%	50%	3%	55%
6	100%	100%	0%	0%	75%	2%	55%
7	100%	100%	95%	95%	75%	0%	10%
8	100%	100%	100%	100%	50%	0%	0%
9	100%	100%	98%	90%	70%	0%	0%

5.3.2.4. Staunton River Load Allocation

The scenarios considered for Staunton River load allocation are presented in **Table 5-8**. The following conclusions can be made:

1. In Scenario 0 (existing conditions), the water quality standard was violated most of the time in the Staunton River.
2. In Scenario 3, elimination of the human sources (failed septic systems and straight pipes) and the livestock direct instream loading resulted in a 23 percent violation of this standard in the Staunton River and a 100 percent violation of the E. coli instantaneous standard.

3. In Scenario 4, eliminating all sources except direct instream loading from wildlife resulted in a 15 percent violation of this standard in the Staunton River and a 100 percent violation of the E. coli instantaneous standard.
4. No violations of either the E. coli geometric mean standard or the instantaneous E. coli standard occurred in the Staunton River under Scenario 9.

Therefore, Scenario 9 was chosen as the final TMDL load allocation scenario for the Staunton River. Under this scenario, complete elimination of the human sources (failed septic systems and straight pipes), livestock direct deposition, and a 75 percent reduction of urban non-point sources and a 90 percent reduction of agricultural non-point sources, and a 70 percent reduction of direct loading by wildlife are required.

Table 5-8: Staunton River Load Reductions under 30-Day Geometric Mean and Instantaneous Standards for E. coli

Scenario	Failed Septic & Pipes	Direct Livestock	NPS (Agric-cultural)	NPS (Urban)	Direct Wildlife	E. coli Percent violation of GM standard 126 #/100ml	E coli Percent violation of Inst. standard 235 #/100ml
0	0%	0%	0%	0%	0%	76%	100%
1	100%	0%	0%	0%	0%	53%	100%
2	100%	50%	0%	0%	0%	36%	100%
3	100%	100%	0%	0%	0%	23%	100%
4	100%	100%	100%	100%	0%	15%	100%
5	100%	100%	0%	0%	50%	0%	47%
6	100%	100%	0%	0%	75%	0%	40%
7	100%	100%	95%	95%	75%	0%	7%
8	100	100	100	100	50	0%	0%
9	100%	100%	75%	90%	70%	0%	0%

5.4 TMDL Summary

Based on the load allocation scenario analyses, the TMDL allocation plans are summarized below:

5.4.1 Cub Creek Allocation Plan

As shown in **Table 5-5**, scenario 9 will meet 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml for Cub Creek. The requirements for this scenario are:

- 100 % reduction of the human sources (failed septic systems and straight pipes).
- 100 % reduction of the direct instream loading from livestock.
- 99.5% reduction of bacteria loading from agricultural and urban non-point sources.
- 90% reduction of the direct instream loading from wildlife.

Table 5-9 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix D.

Table 5-9: Cub Creek Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	6.75E+11	3.38E+10	95%
Cropland	6.12E+11	3.06E+10	95%
Pasture	3.39E+12	1.69E+11	95%
Low Density Residential	5.95E+12	2.98E+11	95%
Commercial/Industrial	1.59E+10	7.94E+08	95%
Water/Wetland	9.63E+09	4.81E+08	95%
High Density Residential	2.80E+10	1.40E+09	95%
Failed Septic - direct deposition	5.04E+11	0.00E+00	100%
Wildlife - direct deposition	3.22E+12	9.66E+11	70%
Cattle - direct deposition	1.83E+12	0.00E+00	100%
Point Source	2.87E+10	2.87E+10	0.0%
Total loads /Overall reduction	**1.63E+13**	**1.53E+12**	**91%**

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan are presented in **Figure 5-1** and **Figure 5-2. Figure 5-1** shows the 30-day geometric mean E. coli loading after applying the allocations of Scenario 9, as well as geometric mean loading under existing conditions**. Figure 5-2** shows the instantaneous E. coli loadings also under the allocations of Scenario 9 as well as the loading under existing conditions. For Cub Creek, allocation Scenario 9 results in bacteria concentrations that are consistently below both the geometric mean and instantaneous standards for E. coli. A summary of the TMDL allocation plan loads for Cub Creek is presented in **Table 5-10**.

Table 5-10: Cub Creek TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
2.87E+10	**1.50E+12**	**Implicit**	**1.53E+12**

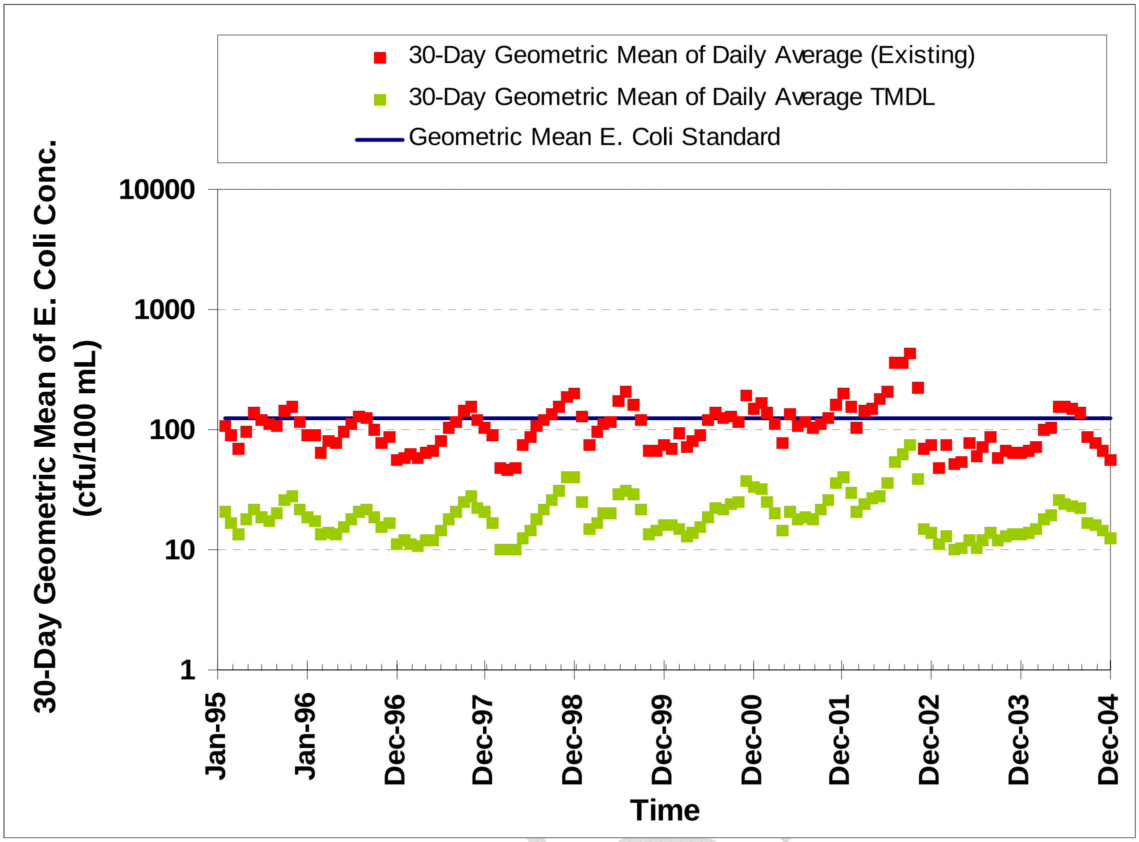


Figure 5-1: Cub Creek Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 9

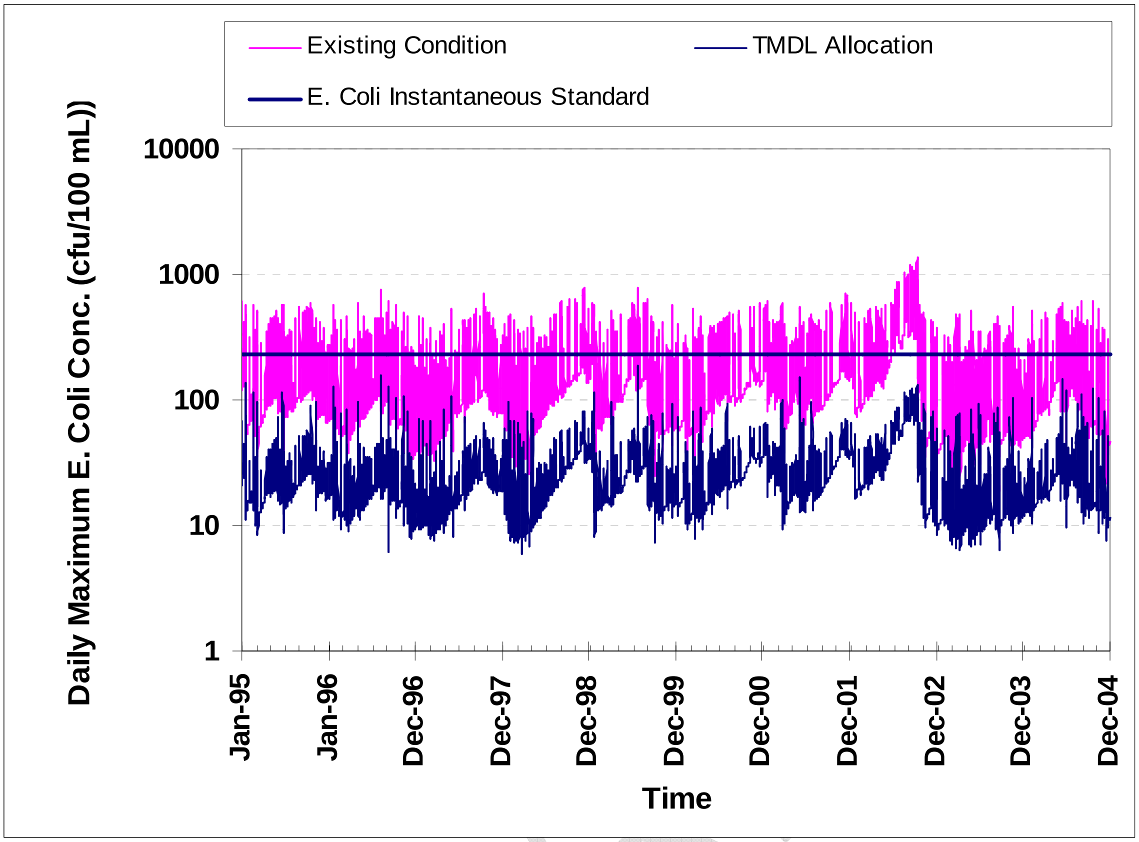


Figure 5-2: Cub Creek Instantaneous E. coli Loadings under Allocation Scenario 9

5.4.2 Turnip Creek Allocation Plan

For Turnip Creek, as shown in **Table 5-6**, Scenario 9 will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml. The requirements for this scenario include:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 99.5 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 93 percent reduction of the direct instream loading from wildlife.

Table 5-11 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix D.

Table 5-11: Turnip Creek Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	2.39E+11	2.39E+10	90%
Cropland	3.50E+11	3.50E+10	90%
Pasture	1.35E+12	1.35E+11	90%
Low Density Residential	1.09E+12	1.09E+11	90%
Commercial/Industrial	9.17E+08	9.17E+07	90%
Water/Wetland	4.10E+09	4.10E+08	90%
Failed Septic - direct deposition	2.64E+11	0.00E+00	100%
Wildlife - direct deposition	1.19E+12	3.57E+11	70%
Cattle - direct deposition	6.66E+11	0.00E+00	100%
Point Source	2.61E+09	2.61E+09	0.0%
Total loads /Overall reduction	5.16E+12	6.63E+11	87%

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan for the Turnip Creek are presented in **Figure 5-3** and **Figure 5-4**. **Figure 5-3** shows the 30-day geometric mean E. coli loading after applying allocation Scenario 9, as well as geometric mean loading under existing conditions. **Figure 5-4** shows the instantaneous E. coli loading after applying allocation Scenario 9 as well as existing conditions. A summary of the TMDL allocation plan loads for the Turnip Creek is presented in **Table 5-12**.

Table 5-12: Turnip Creek TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
2.61E+09	**6.61E+11**	**Implicit**	**6.63E+11**

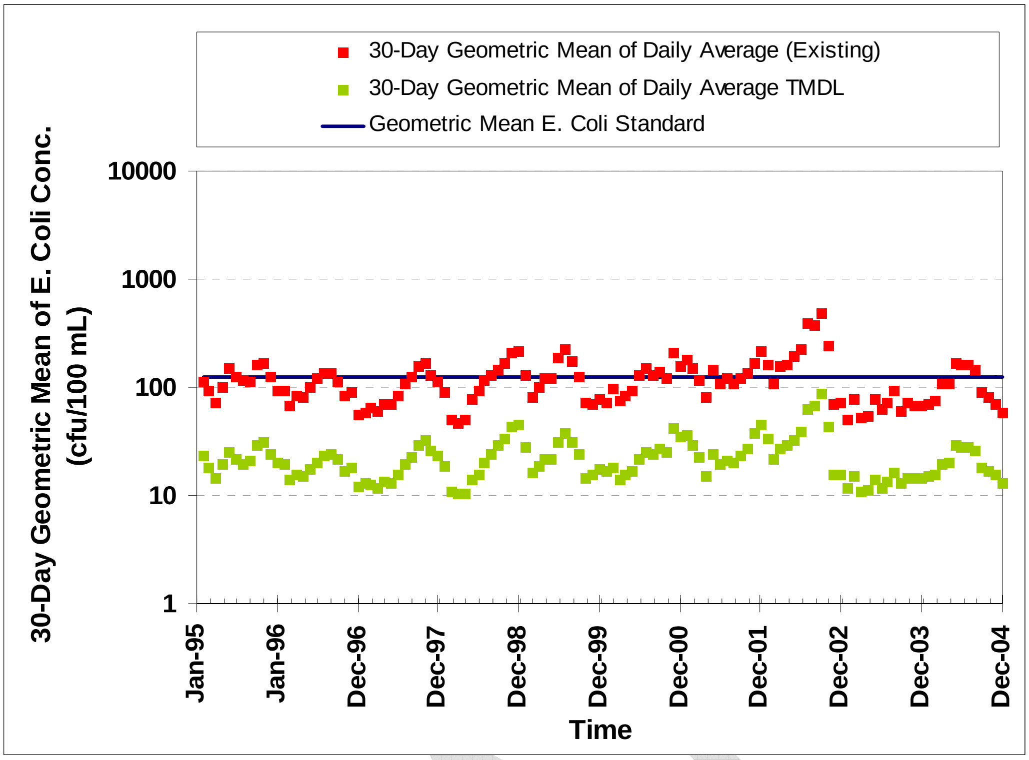


Figure 5-3: Turnip Creek Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 9

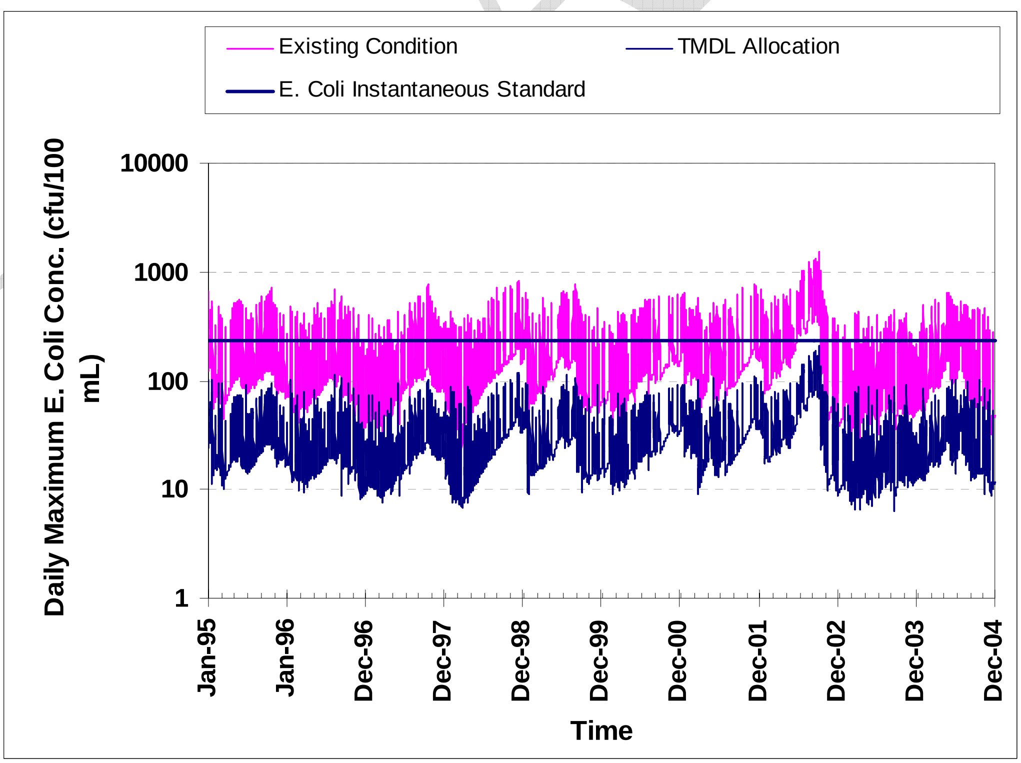


Figure 5-4: Turnip Creek Instantaneous E. coli Loadings under Allocation Scenario 9

5.4.3 Buffalo Creek Allocation Plan

For Buffalo Creek, as shown in **Table 5-7**, Scenario 9 will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml. The requirements for this scenario include:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 99.5 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 93 percent reduction of the direct instream loading from wildlife.

Table 5-13 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix D.

Table 5-13: Buffalo Creek Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	9.88E+09	1.96E+08	98%
Cropland	2.92E+10	5.78E+08	98%
Pasture	8.13E+10	1.61E+09	98%
High Density Residential	8.19E+07	1.62E+06	98%
Wildlife - direct deposition	4.70E+10	1.40E+10	70%
Point Source	0.00E+00	1.65E+08*	0.0%
Total loads /Overall reduction	1.67E+11	≤1.65E+10	90%

* Waste load allocations for watersheds without permitted point sources are denoted as ≤1% based on Virginia DEQ guidance.

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan for the Buffalo Creek are presented in **Figure 5-5 and Figure 5-6**. **Figure 5-5** shows the 30-day geometric mean E. coli loading after applying allocation Scenario 9, as well as geometric mean loading under existing conditions. **Figure 5-6** shows the instantaneous E. coli loading after applying allocation Scenario 9. A summary of the TMDL allocation plan loads for Buffalo Creek is presented in **Table 5-14**.

Table 5-14: Buffalo Creek TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
≤1.65E+8*	**1.64E+10**	**Implicit**	**1.65E+10**

* Waste load allocations for watersheds without permitted point sources are denoted as ≤1% based on Virginia DEQ guidance.

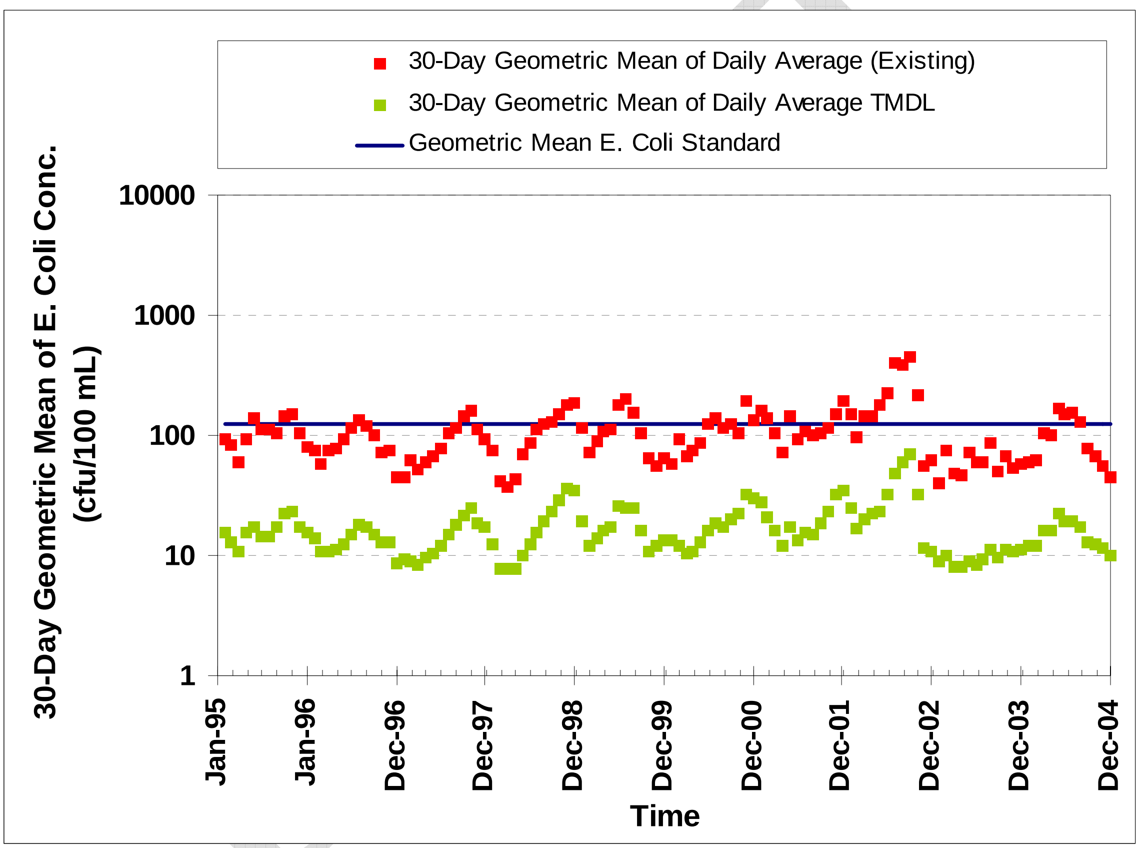


Figure 5-5: Buffalo Creek Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 9

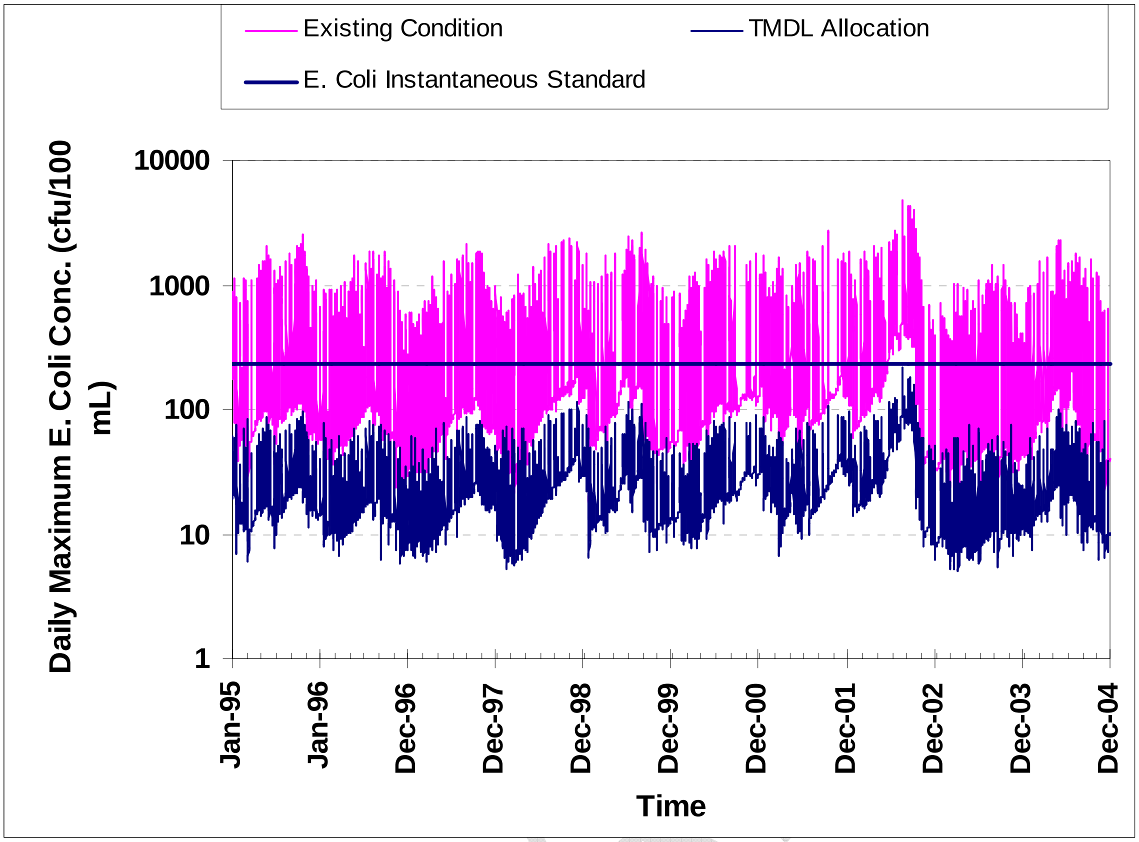


Figure 5-6: Buffalo Creek Instantaneous E. coli Loadings under Allocation Scenario 9

5.4.4 Staunton River Allocation Plan

As shown in **Table 5-8**, Scenario 8 for the Staunton River, will meet the 30-day E. coli geometric mean water quality standard of 126 cfu/100 ml and the instantaneous water quality standard of 235 cfu/100ml. The requirements necessary to met scenario 8 include:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98.8 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 68 percent reduction of the direct instream loading from wildlife.

Table 5-15 shows the distribution of the annual average E. coli load under existing conditions and under the TMDL allocation, by land use and source. The monthly distribution of these loads is presented in Appendix D.

Table 5-15: Staunton River Distribution of Annual Average E. Coli Load under Existing Conditions and TMDL Allocation

Land Use/Source	Annual Average E. coli Loads (cfu/yr)		Percent Reduction (%)
	Existing	Allocation	
Forest	7.79E+12	1.95E+12	75%
Cropland	1.05E+13	2.63E+12	75%
Pasture	4.40E+13	1.10E+13	75%
Low Density Residential	1.07E+14	2.67E+13	75%
Commercial/Industrial	6.50E+11	1.62E+11	75%
Water/Wetland	1.03E+11	2.58E+10	75%
High Density Residential	2.05E+11	5.11E+10	75%
Failed Septic - direct deposition	2.60E+13	0.00E+00	100%
Wildlife - direct deposition	3.93E+13	1.18E+13	70%
Cattle - direct deposition	1.77E+13	0.00E+00	100%
Point Source	2.34E+13	2.34E+13	0.0%
Total loads /Overall reduction	2.77E+14	7.77E+13	72%

The resulting geometric mean and instantaneous E. coli concentrations under the TMDL allocation plan are presented in **Figure 5-6 and Figure 5-7**. **Figure 5-6** shows the 30-day geometric mean E. coli loading after applying allocation Scenario 8, as well as geometric mean loading under existing conditions. **Figure 5-7** shows the instantaneous E. coli loading after applying allocation Scenario 8. A summary of the TMDL allocation plan loads for the Staunton River is presented in **Table 5-14**.

Table 5-14: Staunton River TMDL Allocation Plan Loads (cfu/year) for E. coli

Point Sources (WLA)	Non-point sources (LA)	Margin of safety (MOS)	TMDL
2.34E+13	**5.43E+13**	**Implicit**	**7.77E+13**

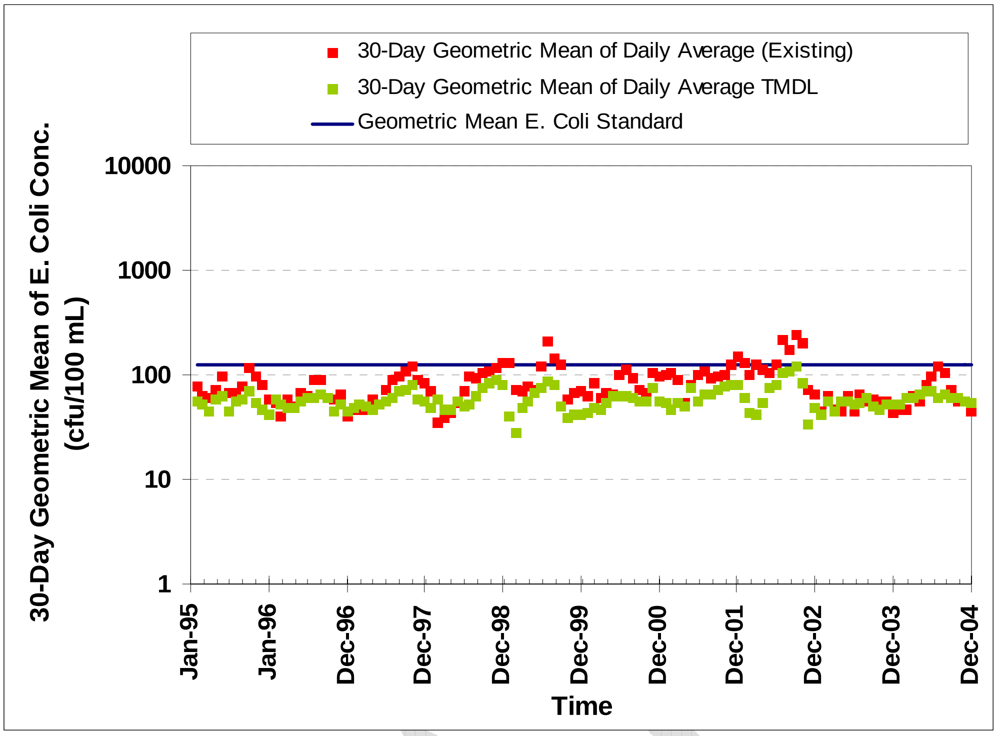


Figure 5-6: Staunton River Geometric Mean E. coli Loadings under Existing Conditions and Allocation Scenario 8

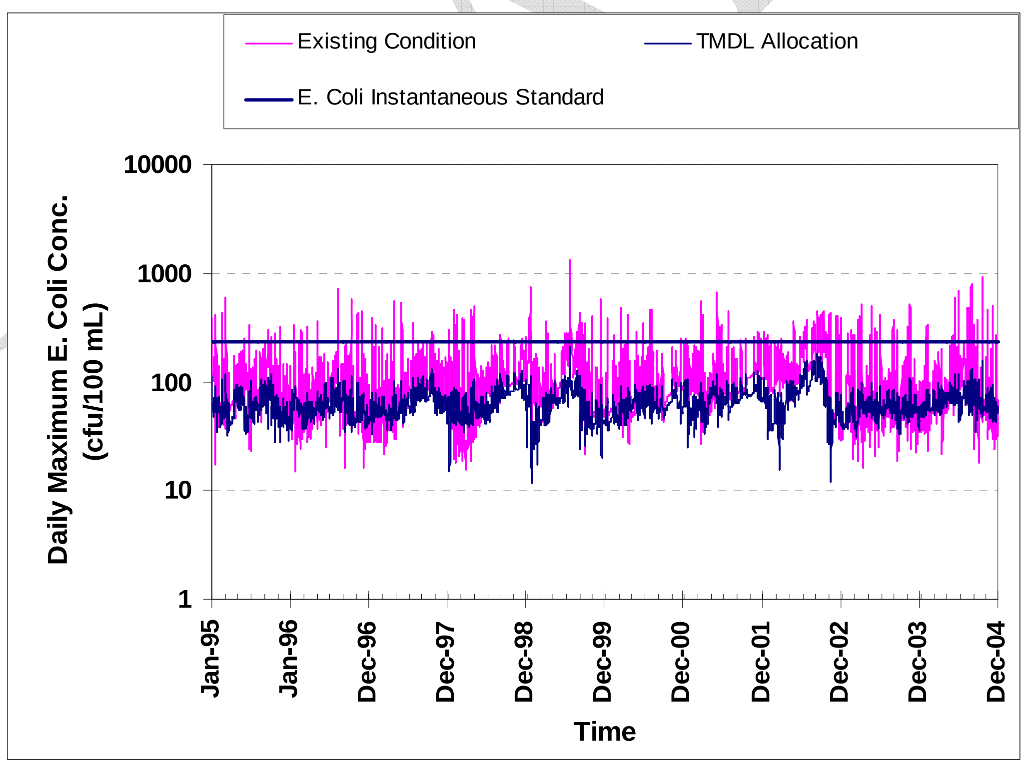


Figure 5-7: Staunton River Instantaneous E. coli Loadings under Allocation Scenario 8

6.0 TMDL Implementation

The goal of the TMDL program is to establish a three-step path that will lead to attainment of water quality standards. The first step in the process is to develop TMDLs that will result in meeting water quality standards. This report represents the culmination of that effort for the bacteria impairments on Cub Creek, Turnip Creek, Buffalo Creek (UT), and the Staunton River. The second step is to develop a TMDL implementation plan. The final step is to implement the TMDL implementation plan, and to monitor stream water quality to determine if water quality standards are being attained.

Once a TMDL has been approved by EPA, measures must be taken to reduce pollution levels from both point and non point sources in the stream (see section 6.4.2). For point sources, all new or revised VPDES/NPDES permits must be consistent with the TMDL WLA pursuant to 40 CFR 122.44 (d)(1)(vii)(B) and must be submitted to EPA for approval. The measures for non point source reductions, which can include the use of better treatment technology and the installation of best management practices (BMPs), are implemented in an iterative process that is described along with specific BMPs in the implementation plan. The process for developing an implementation plan has been described in the "TMDL Implementation Plan Guidance Manual", published in July 2003 and available upon request from the DEQ and DCR TMDL project staff or at http://www.deq.virginia.gov/tmdl/implans/ipguide.pdf With successful completion of implementation plans, local stakeholders will have a blueprint to restore impaired waters and enhance the value of their land and water resources. Additionally, development of an approved implementation plan may enhance opportunities for obtaining financial and technical assistance during implementation.

6.1 *Staged Implementation*

In general, Virginia intends for the required bacteria reductions to be implemented in an iterative process that first addresses those sources with the largest impact on water quality. For example, in agricultural areas of the watershed, the most promising management practice is livestock exclusion from streams. This has been shown to be very effective in lowering bacteria concentrations in streams, both by reducing the cattle deposits themselves and by providing additional riparian buffers.

Additionally, in both urban and rural areas, reducing the human bacteria loading from failing septic systems should be a primary implementation focus because of its health implications. This component could be implemented through education on septic tank pump-outs as well as a septic system repair/replacement program and the use of alternative waste treatment systems.

In urban areas, reducing the human bacteria loading from leaking sewer lines could be accomplished through a sanitary sewer inspection and management program. Other BMPs that might be appropriate for controlling urban wash-off from parking lots and roads and that could be readily implemented may include more restrictive ordinances to reduce fecal loads from pets, improved garbage collection and control, and improved street cleaning.

The iterative implementation of BMPs in the watershed has several benefits:

1. It enables tracking of water quality improvements following BMP implementation through follow-up stream monitoring;

2. It provides a measure of quality control, given the uncertainties inherent in computer simulation modeling;

3. It provides a mechanism for developing public support through periodic updates on BMP implementation and water quality improvements;

4. It helps ensure that the most cost effective practices are implemented first; and

5. It allows for the evaluation of the adequacy of the TMDL in achieving water quality standards.

Watershed stakeholders will have opportunity to participate in the development of the TMDL implementation plan. While specific goals for BMP implementation will be established as part of the implementation plan development, the following stage 1 scenarios are targeted at controllable, anthropogenic bacteria sources and can serve as starting points for targeting BMP implementation activities.

6.2 Stage 1 TMDL Implementation Scenarios

The goal of the stage 1 scenarios is to reduce the bacteria loadings from controllable sources (excluding wildlife) such that violations of the single sample maximum criterion (235 cfu/100mL) are less than 10 percent. The stage 1 scenarios were generated with the same model setup as was used for the TMDL allocation scenarios. A margin of safety was not used in determining the stage 1 scenarios

Three scenarios are presented in **Tables 6-1** through **6-4** for Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River respectively. Scenario 1 represents the required load reduction that will not exceed the instantaneous standard by more than 10% violation. Scenarios 2 and 3 represent the implementation of BMPs and management strategies such as livestock exclusion from streams, alternative water, manure storage, riparian buffers, and pet waste control that can be readily put in place in the watershed.

Table 6-1: Cub Creek Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100%	100%	85%	95%	63%	0%	10%
2	100%	50%	50%	50%	0%	12%	100%
3	100%	75%	75%	75%	0%	7%	77%

Table 6-2: Turnip Creek Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100%	100%	85%	95%	63%	0%	10%
2	100%	50%	50%	50%	0%	12%	100%
3	100%	75%	75%	75%	0%	7%	77%

Table 6-3: Buffalo Creek (UT) Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100%	100%	96%	70%	55%	0%	10%
2	100%	50%	50%	50%	0%	10%	100%
3	100%	75%	75%	75%	0%	6%	93%

Table 6-4: Staunton River Phase 1 Scenarios

Scenario	Failed Septics & Pipes	Direct Livestock	NPS (Agricultural)	NPS (Urban)	Direct Wildlife	Percent violation of Inst. standard 235 #/100ml	Percent violation of Inst. standard 235 #/100ml
1	100	100%	52%	90%	70%	1%	10%
2	100	50%	50%	50%	0%	9%	47%
3	100	75%	75%	75%	0%	4%	3%

Under Scenario 1, the E. coli instantaneous standard of 235 cfu/100ml was violated 10 percent of the time at Reach 11 and Reach 19. This condition requires the following reductions:

- 100 percent reduction of the human sources (failed septic systems and straight pipes).
- 100 percent reduction of the direct instream loading from livestock.
- 98 percent reduction of bacteria loading from agricultural and urban non-point sources.
- 5 percent reduction of the direct instream loading from wildlife.

6.3 Link to Ongoing Restoration Efforts

Implementation of this TMDL will contribute to on-going water quality improvement efforts aimed at restoring water quality in the watershed.

6.4 Reasonable Assurance for Implementation

6.4.1 Follow-Up Monitoring

VADEQ will continue monitoring 4-AFRV002.78, 4-AFRV010.99, 4-AFRV017.71, 4-APLP000.40, and 4-AMEY016.00 in accordance with its ambient monitoring program to evaluate reductions in fecal bacteria counts and the effectiveness of TMDL implementation in attainment of water quality standards.

Monitoring stations 4-AFRV002.78, 4-AFRV010.99, and 4-AMEY016.00 are trend stations and will continue to be monitored on a monthly basis. The other stations are watershed stations with bi-monthly monitoring for a two-year period occurring every six years.

6.4.2 Regulatory Framework

While section 303(d) of the Clean Water Act and current EPA regulations do not require the development of TMDL implementation plans as part of the TMDL process, they do require reasonable assurance that the load and wasteload allocations can and will be implemented. Additionally, Virginia's 1997 Water Quality Monitoring Information and Restoration Act (the "Act") directs the State Water Control Board to "develop and implement a plan to achieve fully supporting status for impaired waters" (Section 62.1-44.19.7). The Act also establishes that the implementation plan shall include the date of expected achievement of water quality objectives, measurable goals, corrective actions necessary and the associated costs, benefits and environmental impacts of addressing the impairments. EPA outlines the minimum elements of an approvable implementation plan in its 1999 "Guidance for Water Quality-Based Decisions: The TMDL Process." The listed elements include implementation actions/management measures, timelines, legal or regulatory controls, time required to attain water quality standards, monitoring plans, and milestones for attaining water quality standards.

Watershed stakeholders will have opportunities to provide input and to participate in the development of the implementation plan, which will also be supported by regional and local offices of DEQ, DCR, and other cooperating agencies.

Once developed, DEQ intends to incorporate the TMDL implementation plan into the appropriate Water Quality Management Plan (WQMP), in accordance with the Clean Water Act's Section 303(e). In response to a Memorandum of Understanding (MOU) between EPA and DEQ, DEQ also submitted a draft Continuous Planning Process to EPA in which DEQ commits to regularly updating the WQMPs. Thus, the WQMPs will be, among other things, the repository for all TMDLs and TMDL implementation plans developed within a river basin.

6.4.3 Implementation Funding Sources

One potential source of funding for TMDL implementation is Section 319 of the Clean Water Act. Section 319 funding is a major source of funds for Virginia's Non-point Source Management Program. Other funding sources for implementation include the U.S. Department of Agriculture's Conservation Reserve Enhancement and Environmental Quality Incentive Programs, the Virginia State Revolving Loan Program, and the Virginia Water Quality Improvement Fund. The TMDL Implementation Plan Guidance Manual contains additional information on funding sources, as well as government agencies that might support implementation efforts and suggestions for integrating TMDL implementation with other watershed planning efforts.

6.4.4 Addressing Wildlife Contributions

In some streams for which TMDLs have been developed, water quality modeling indicates that even after removal of all bacteria sources (other than wildlife), the stream will not attain standards under all flow regimes at all times. As is the case for Cub Creek, Turnip Creek, Buffalo Creek (UT), and the Staunton River, these streams may not be able to attain standards without some reduction in wildlife load. Virginia and EPA are not proposing the elimination of wildlife to allow for the attainment of water quality standards. While managing overpopulations of wildlife remains as an option to local stakeholders, the reduction of wildlife or changing a natural background condition is not the intended goal of a TMDL.

To address this issue, Virginia has proposed (during its recent triennial water quality standards review) a new "secondary contact" category for protecting the recreational use in state waters. On March 25, 2003, the Virginia State Water Control Board adopted criteria for "secondary contact recreation" which means "a water-based form of recreation, the practice of which has a low probability for total body immersion or ingestion of waters (examples include but are not limited to wading, boating and fishing)". These new criteria became effective in February 2004 and can be found at http://www.deq.state.va.us/wqs/rule.html.

In order for the new criteria to apply to a specific stream segment, the primary contact recreational use must be removed. To remove a designated use, the state must demonstrate 1) that the use is not an existing use, 2) that downstream uses are protected, and 3) that the source of bacterial contamination is natural and uncontrollable by effluent limitations and by implementing cost-effective and reasonable best management practices for non-point source control (9 VAC 25-260-10). This and other information is collected through a special study called a Use Attainability Analysis (UAA). All site-specific criteria or designated use changes must be adopted as amendments to the water quality standards regulations. Watershed stakeholders and EPA will be able to provide comment during this process. Additional information can be obtained at http://www.deq.state.va.us/wqs/WQS03AUG.pdf.

Based on the above, EPA and Virginia have developed a process to address the wildlife issue. First in this process is the development of a stage 1 scenario such as those presented previously in this chapter. The pollutant reductions in the stage 1 scenario are targeted only at the controllable, anthropogenic bacteria sources identified in the TMDL, setting aside control strategies for wildlife except for cases of overpopulations. During the implementation of the stage 1 scenario, all controllable sources would be reduced to the maximum extent practicable using the iterative approach described in section 6.1 above. DEQ will re-assess water quality in the stream during and subsequent to the implementation of the stage 1 scenario to determine if the water quality standard is attained. This effort will also evaluate if the modeling assumptions were correct. If water quality standards are not being met, a UAA may be initiated to reflect the presence of naturally high bacteria levels due to uncontrollable sources. In some cases, the effort may never have to go to the UAA phase because the water quality standard exceedances attributed to wildlife in the model may have been very small and infrequent and within the margin of error.

7.0 Public Participation

The development of the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River TMDLs would not have been possible without public participation. Two Technical Advisory Committee (TAC) meetings and two public meetings were held in the Cub Creek, Turnip Creek, Buffalo Creek (UT), and Staunton River watershed. The following is a summary of the meeting objectives and attendance.

TAC Meeting No. 1. The first TAC meeting was held in the Town of Brookneal on September 15, 2004 to discuss the process for TMDL development and describe the listed segments of Cub Creek, Turnip Creek, Buffalo Creek (UT), and the Staunton River. In addition, data and information collected was reviewed, and additional data needed for TMDL development was officially requested. Copies of the presentation materials were made available for public distribution. The meeting participants were contacted via email and phone by DEQ.

TAC Meeting No. 2 The second TAC meeting was held in the Town of Brookneal on September 29, 2005 to discuss the sources assessment and present the HSPF hydrology model calibration. Twelve people representing the various State and local government agencies attended this meeting. Copies of the presentation materials were made available for public distribution. The meeting participants were contacted via email and phone by DEQ.

Public Meeting No. 1. The first public meeting was held in the Town of Brookneal on September 7, 2004 to present: a review of the TMDL process; the listed segments of Cub Creek, Turnip Creek, Buffalo Creek (UT), and the Staunton River; the data that resulted in the 303d listing; inventories of livestock, wildlife, and pets; the fecal coliform sources assessment; the calculations used to estimate the total fecal coliform load; to explain the assumptions used in the calculations; and to present the HSPF model. Ten people attended the meeting. Copies of the presentation were made available for public distribution. Public notice for the meeting was reported in *The Virginia Register of Regulations*. During the 30-day comment period, no written comments were received.

Public Meeting No. 2. The Second public meeting will be held in the Town of Brookneal on January 23, 2006 to discuss the sources assessment, present the HSPF model calibration, and discuss the draft TMDL. Copies of the presentation and the executive summary of the Draft TMDL Report will be made available for public distribution. Public notice for the meeting was reported in *The Virginia Register of Regulations*.

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APPENDIX A: Discharge Monitoring Report Data

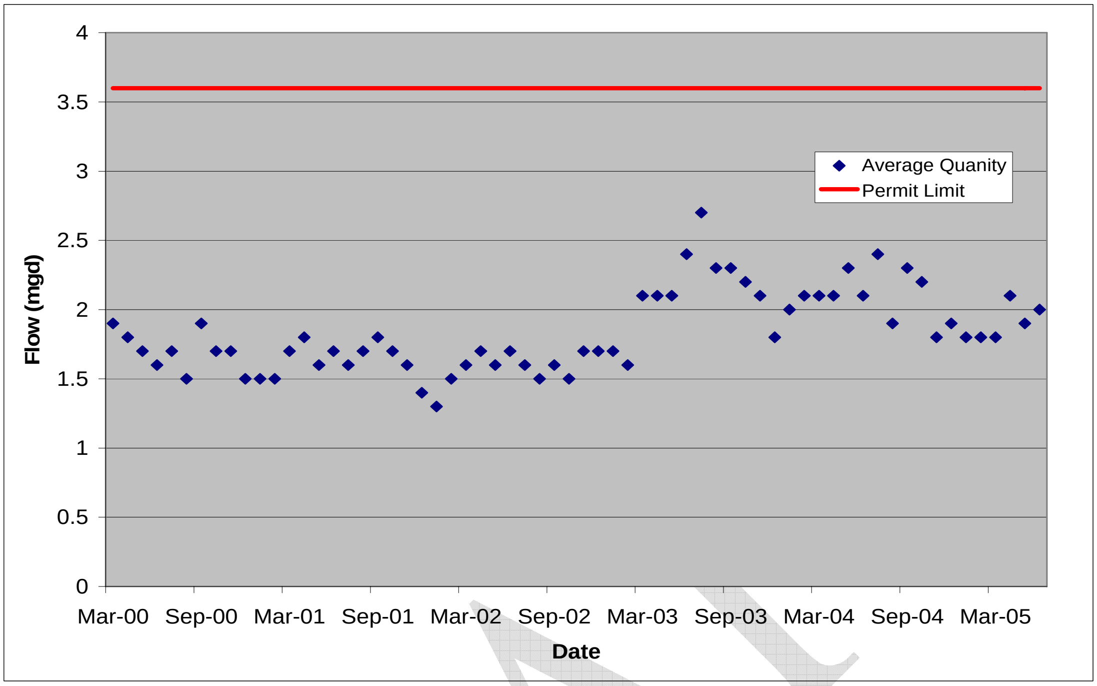


Figure A-1: Altavista Town – Wastewater Treatment Plant Flow Values

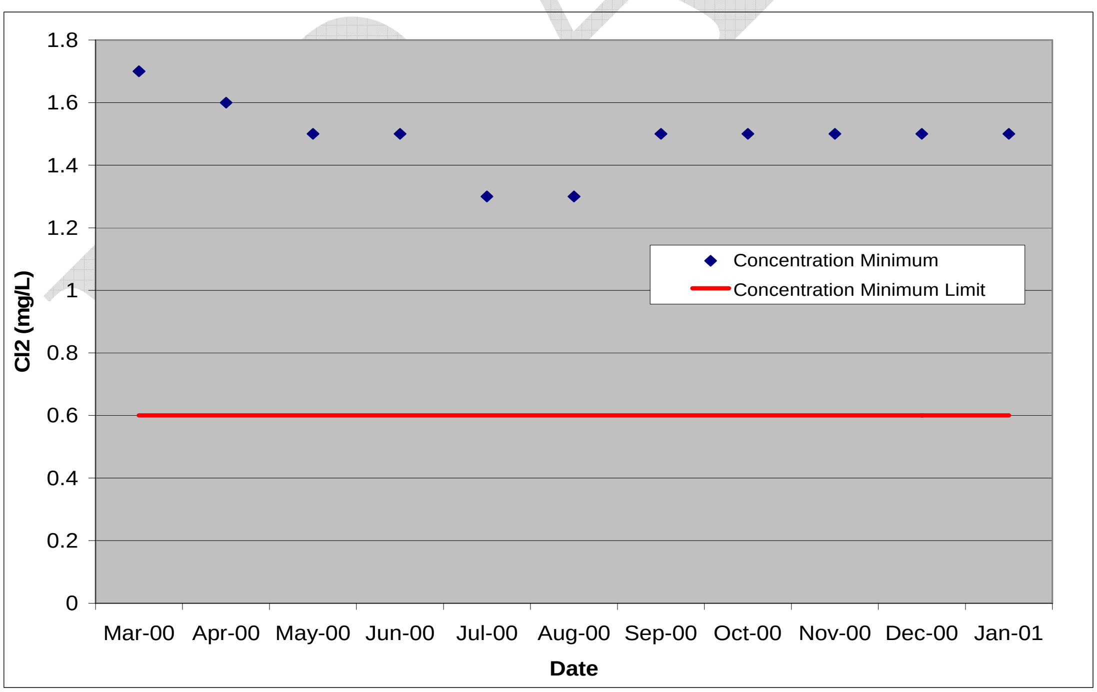


Figure A-2: Altavista Town – Wastewater Treatment Plant Cl_2 Concentrations

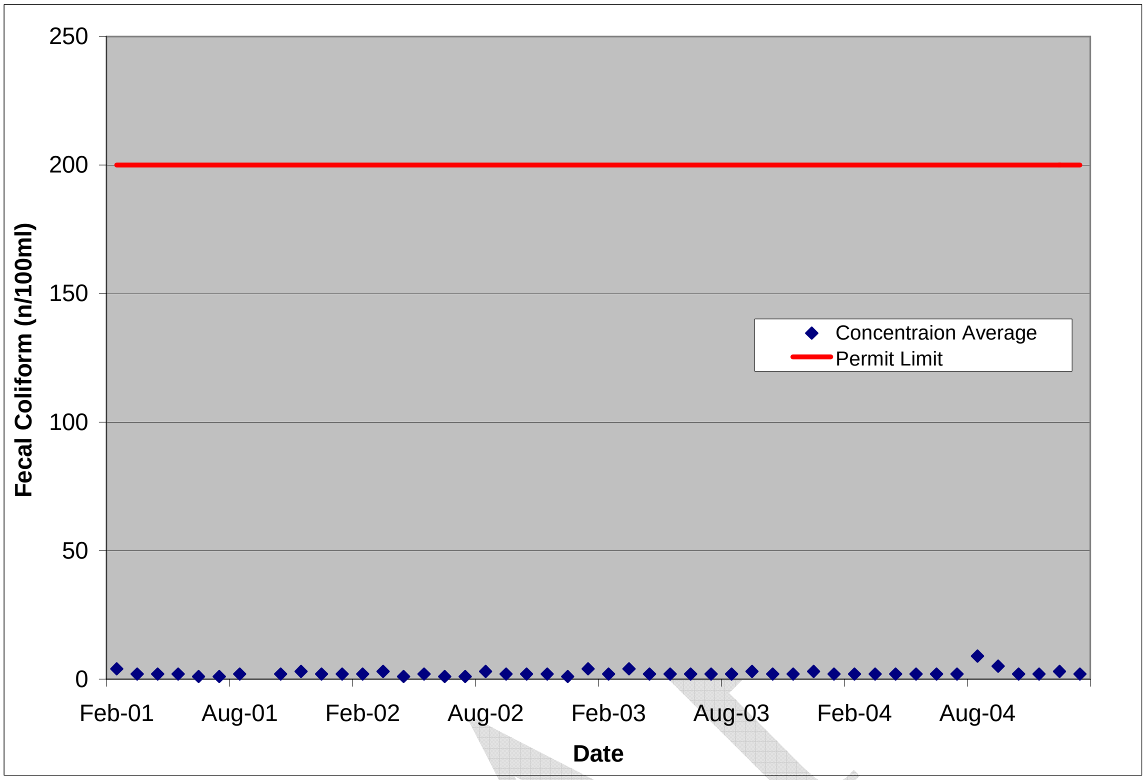


Figure A-3: Altavista Town – Wastewater Treatment Plant Fecal Coliform Concentrations

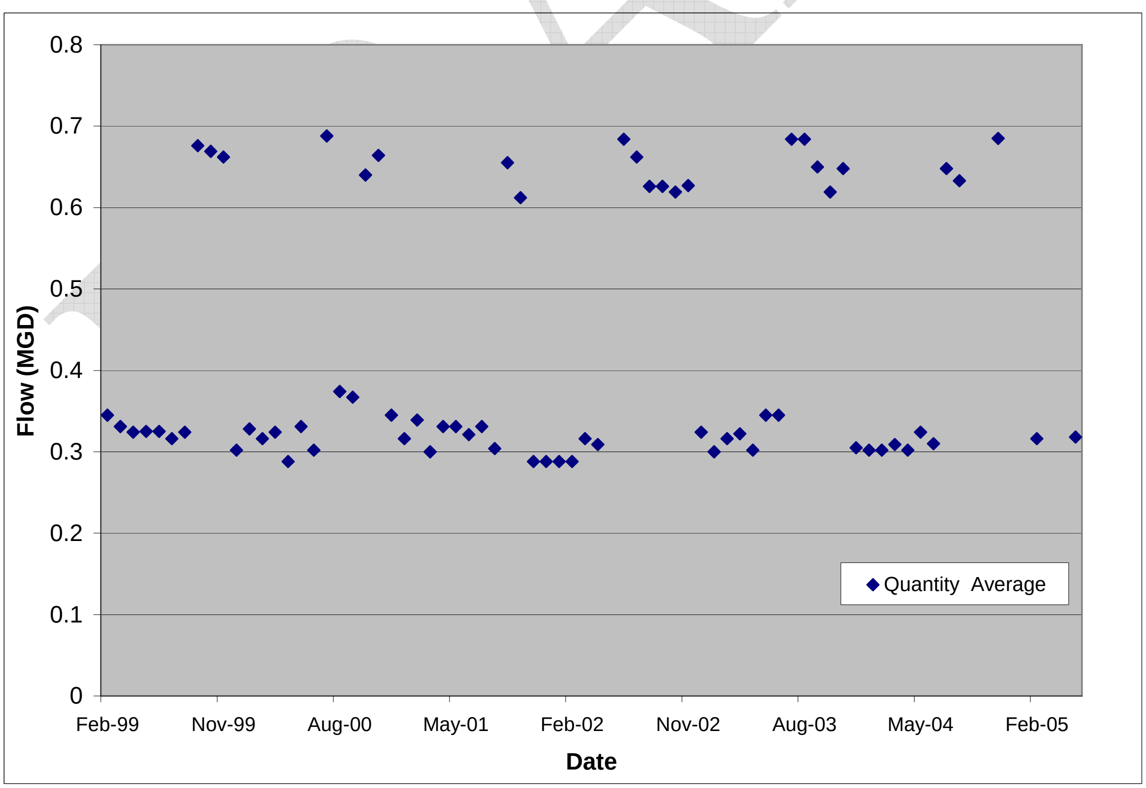


Figure A-4: American Electric Power – Leesville Hydro Plant Outfall 1 Flow Values

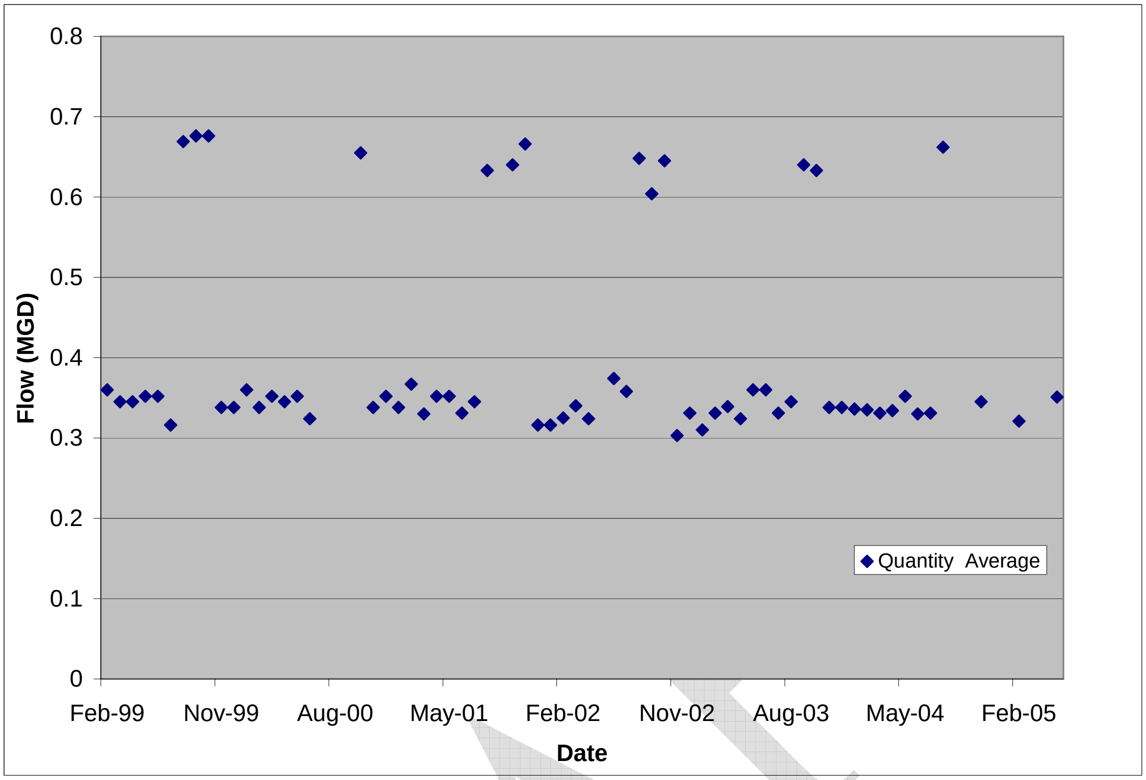


Figure A-5: American Electric Power – Leesville Hydro Plant Outfall 2 Flow Values

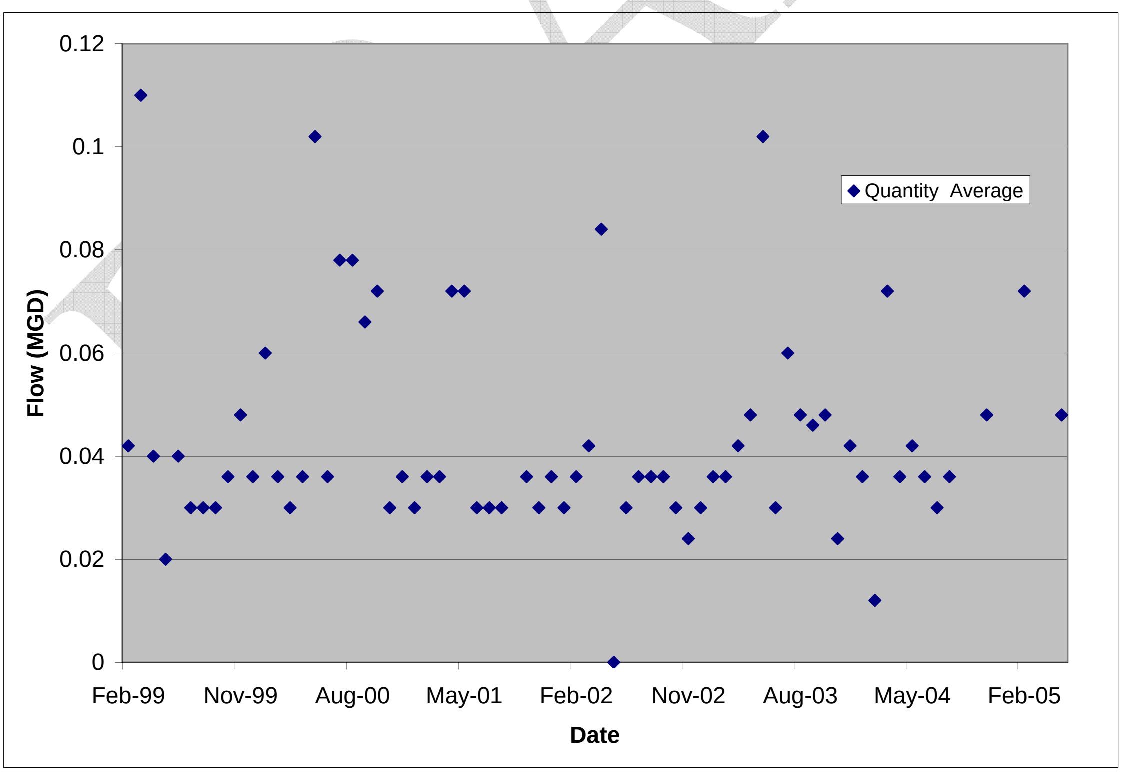


Figure A-6: American Electric Power – Leesville Hydro Plant Outfall 5 Flow Values

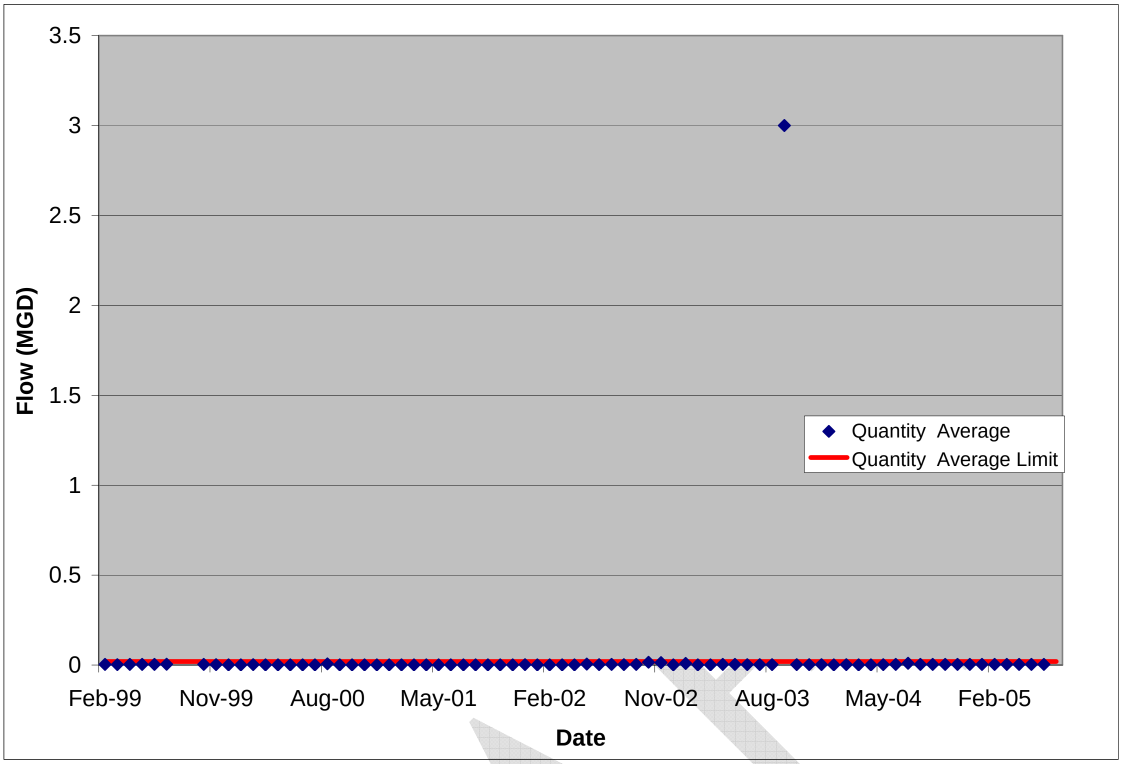


Figure A-7: Bedford County – PSA New Montvale Elementary School Flow Values

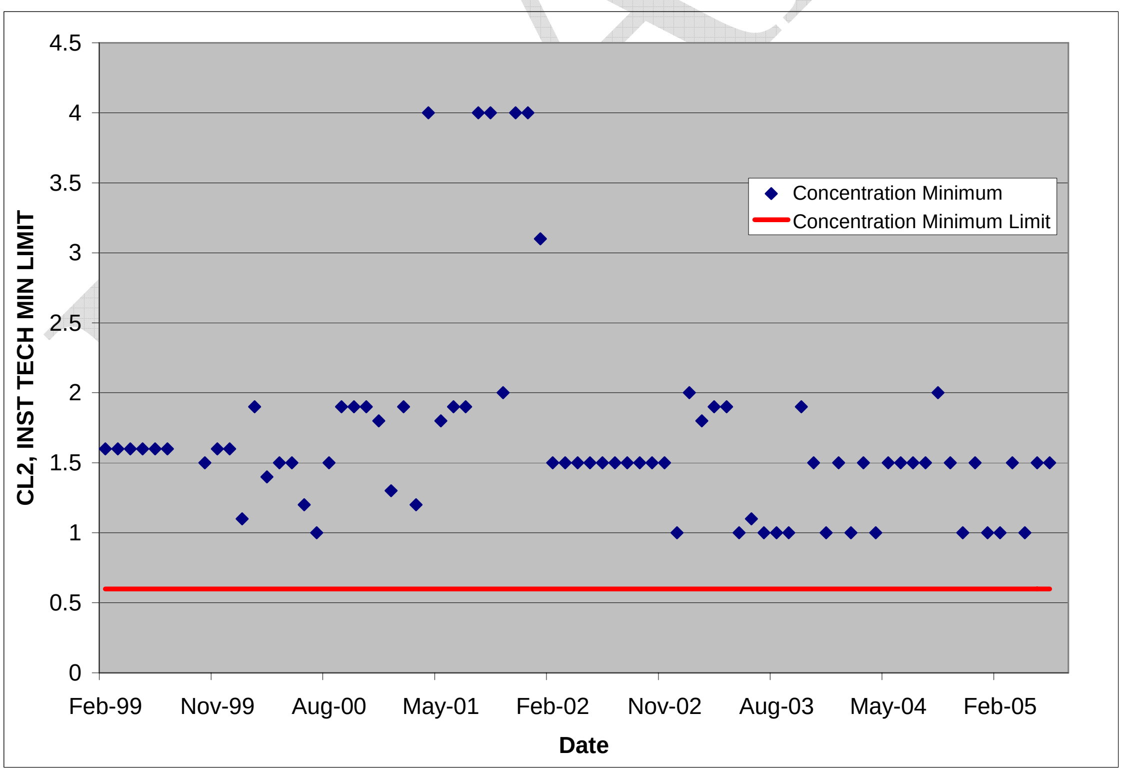


Figure A-8: Bedford County – PSA New Montvale Elementary School Cl2 Concentrations

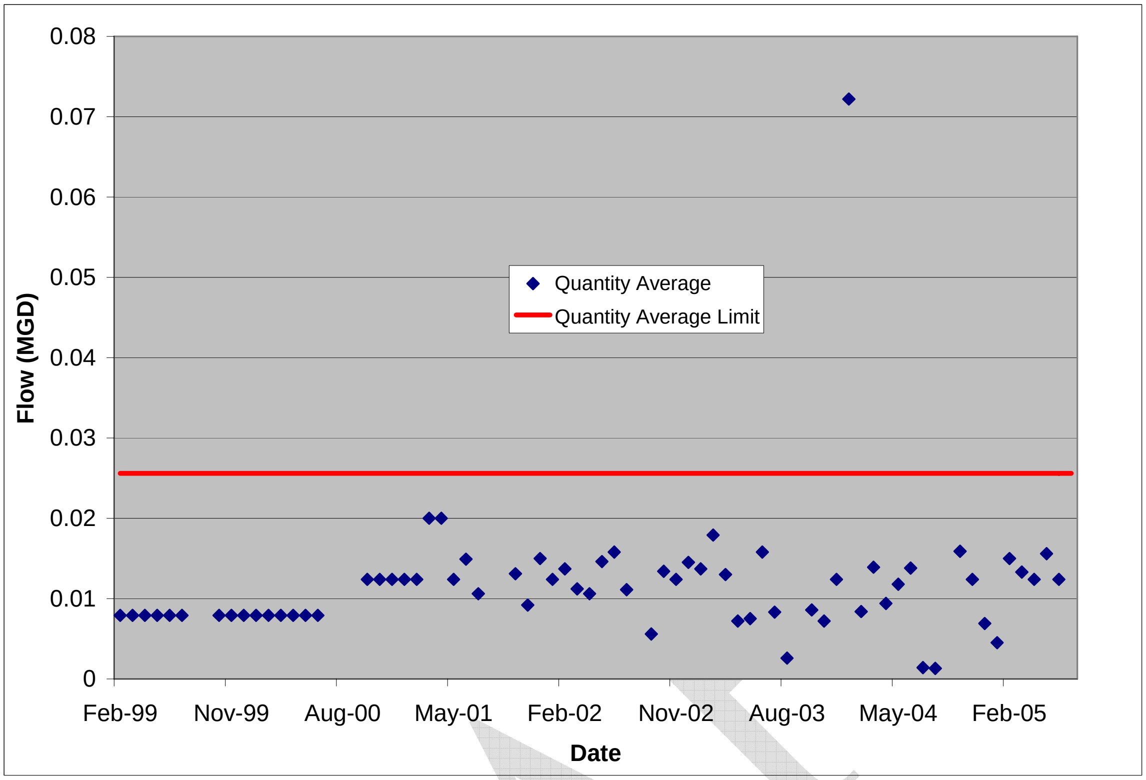


Figure A-9: Bedford County – Staunton River High School Flow Values

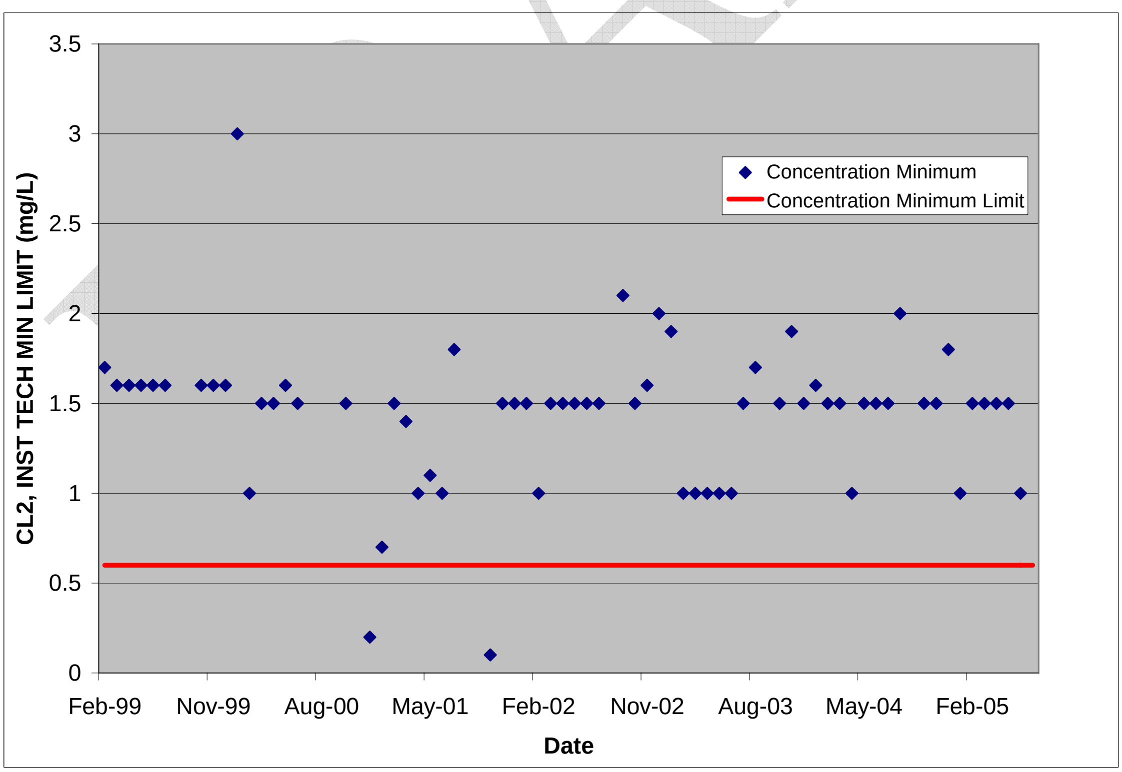


Figure A-10. Bedford County - Staunton River High School Cl_2 Concentrations

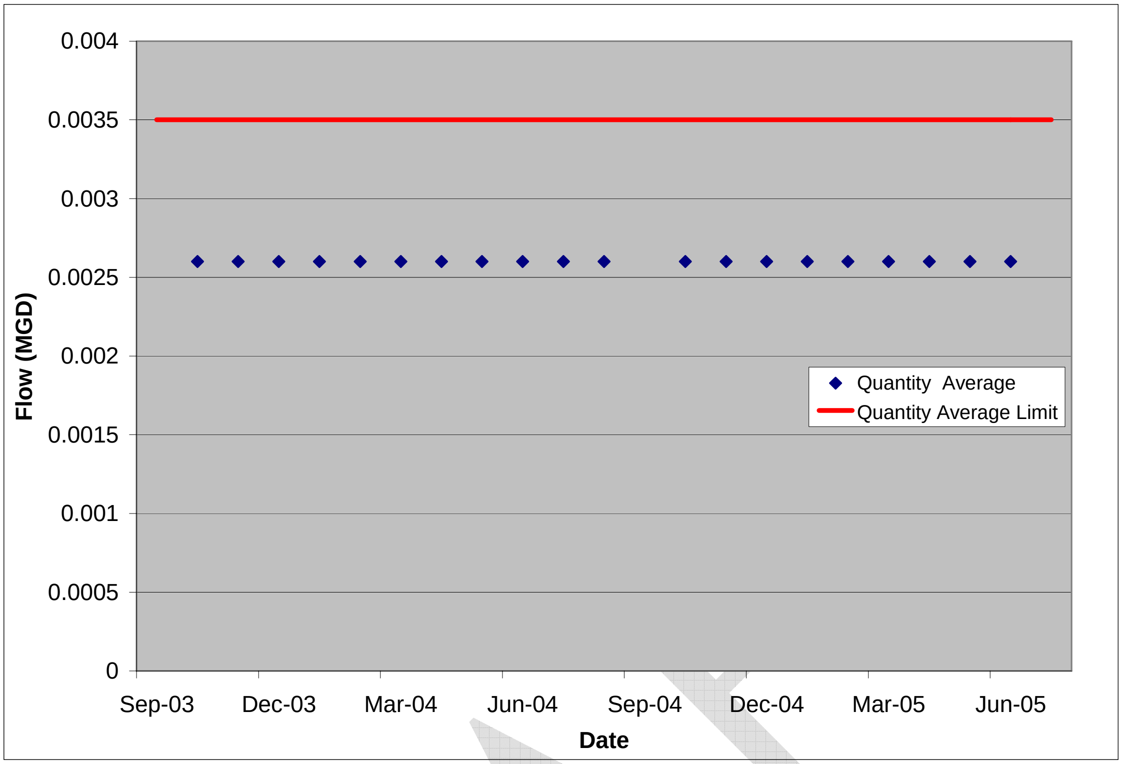


Figure A-11: Bedford County – Thaxton Elementary School Flow Values

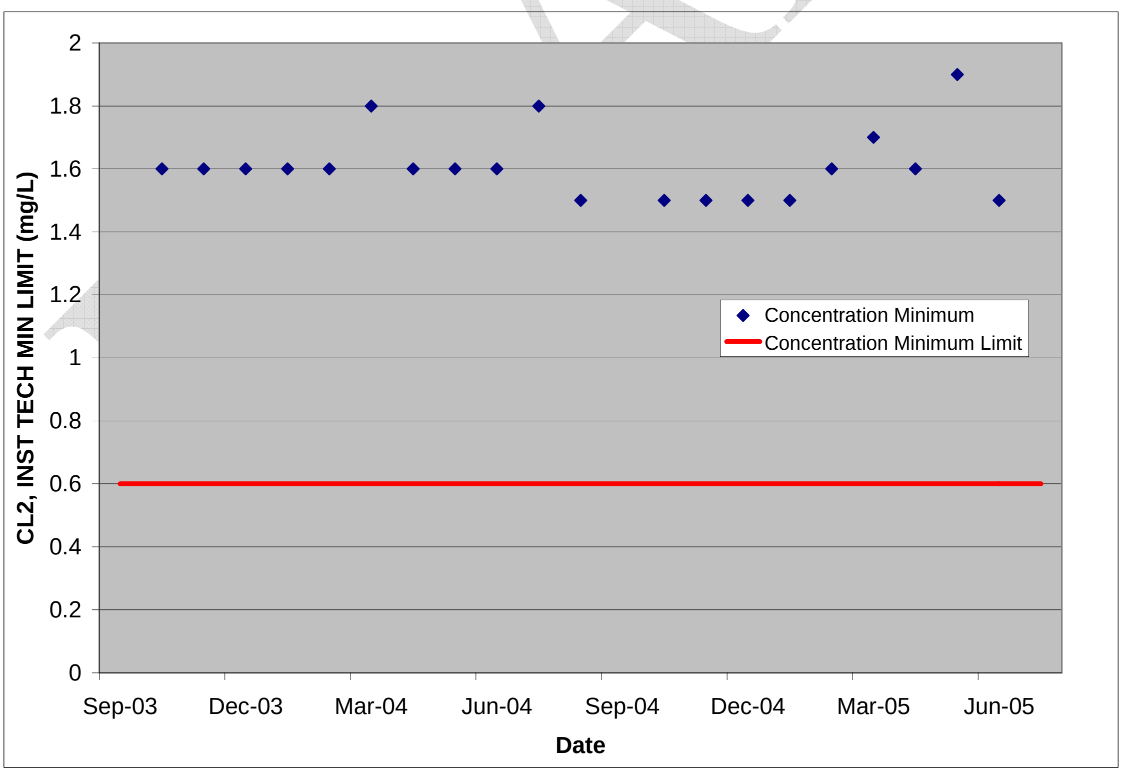


Figure A-12: Bedford County – Thaxton Elementary School Cl2 Concentrations

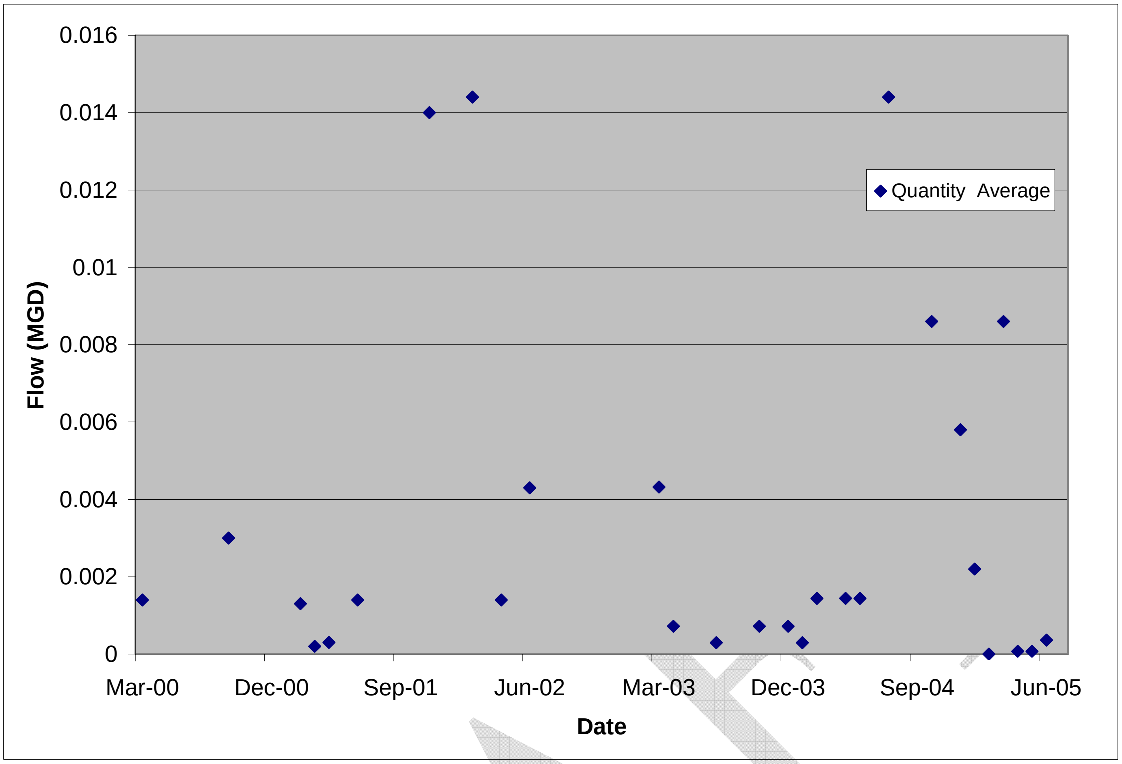


Figure A-13: Blue Ridge Wood Preserving Inc – Outfall 1 Flow Values

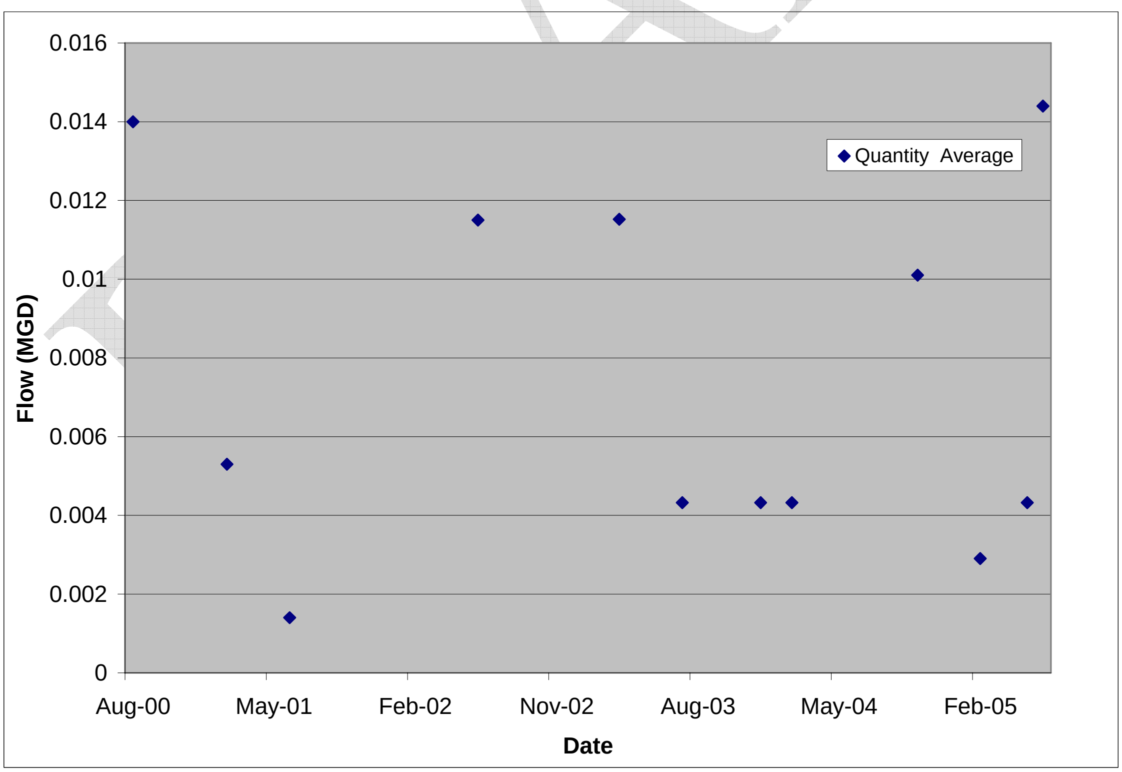


Figure A-14: Blue Ridge Wood Preserving Inc – Outfall 3 low Values

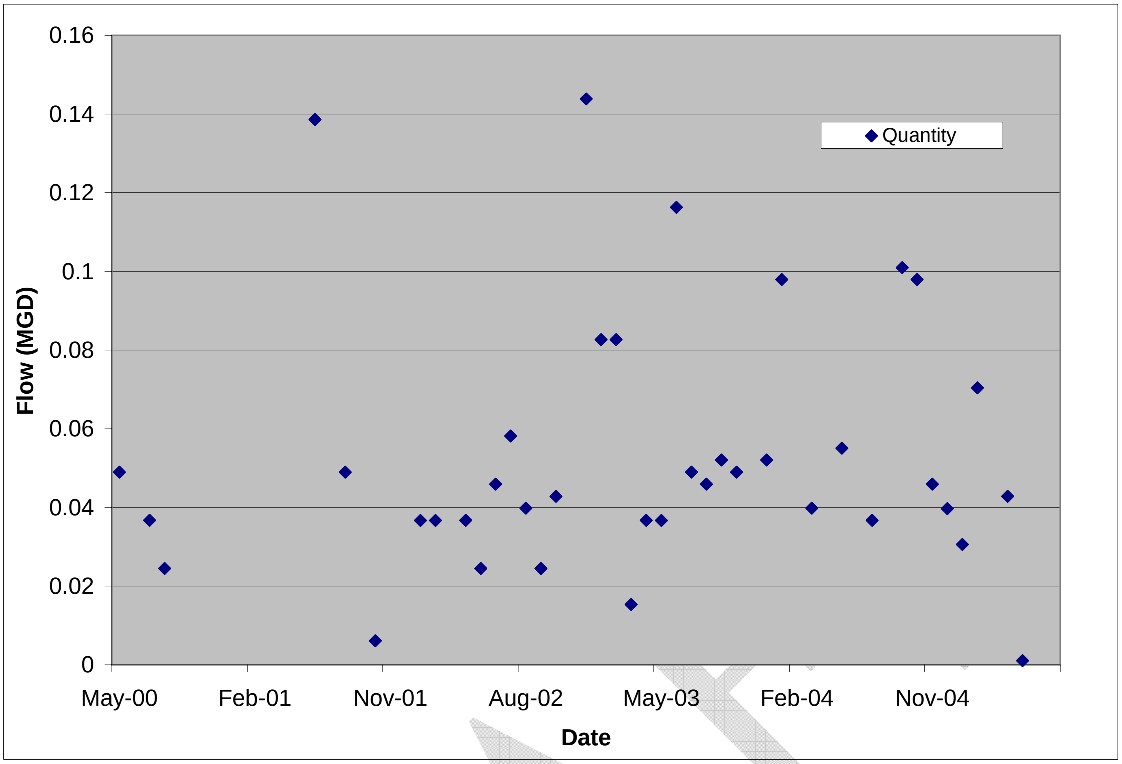


Figure A-15: BP Products North America Inc – Outfall 1 Flow Values

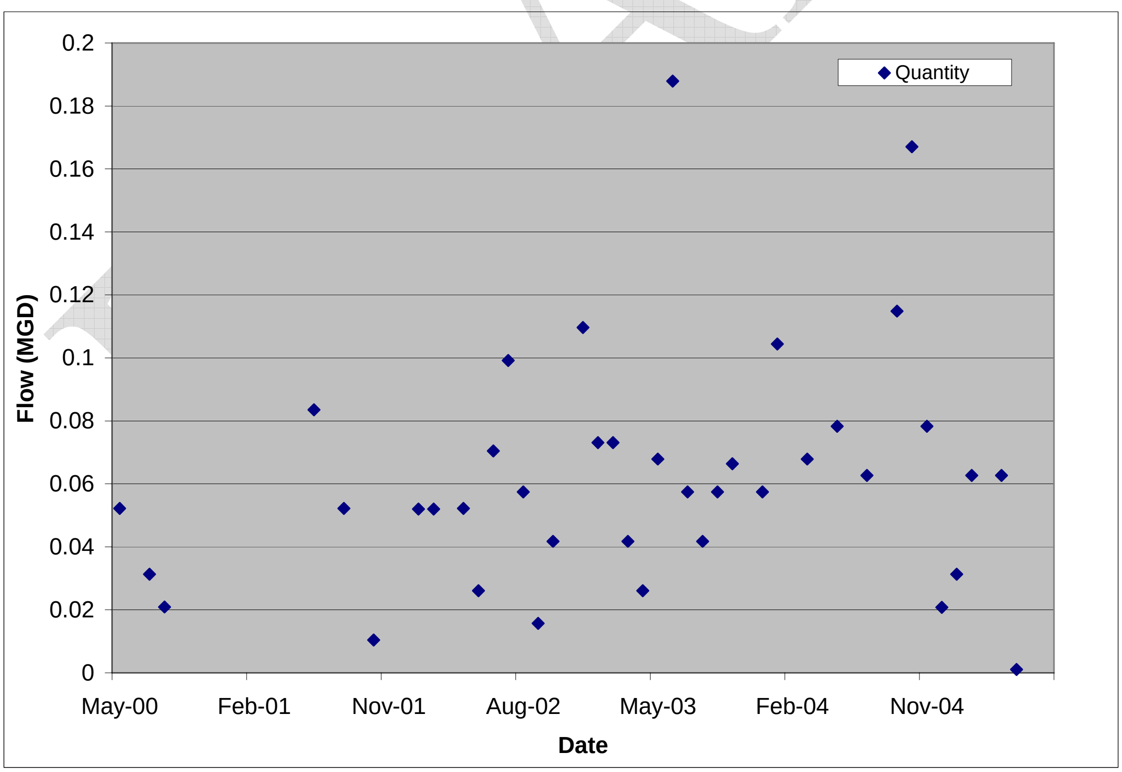


Figure A-16: BP Products North America Inc – Outfall 3 Flow Values

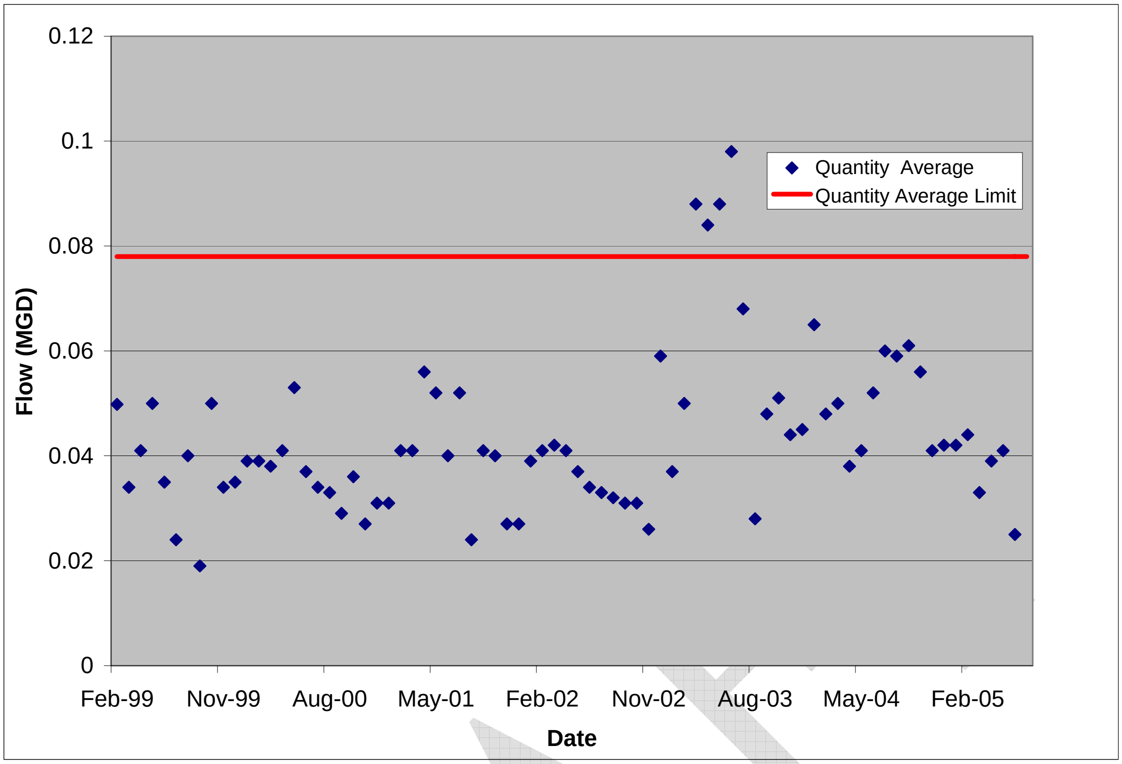


Figure A-17: Brookneal Town – Staunton River Lagoon Flow Values

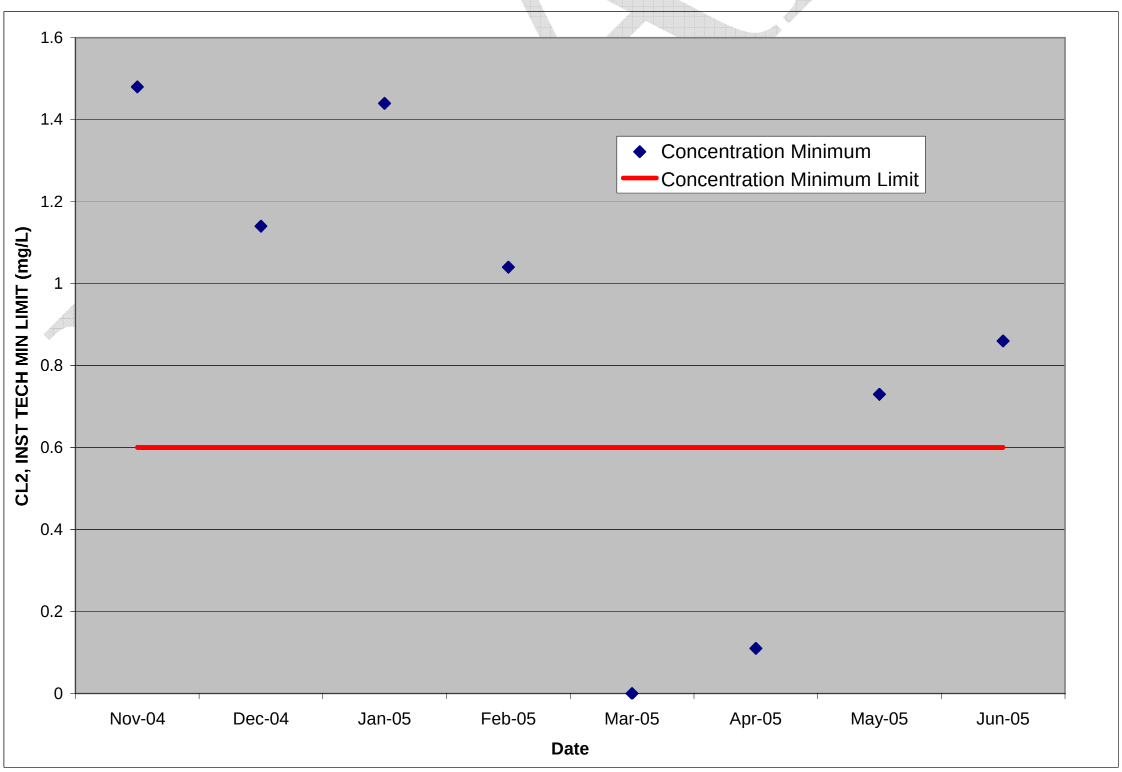


Figure A-18: Brookneal Town – Staunton River Lagoon Cl_2 Concentrations

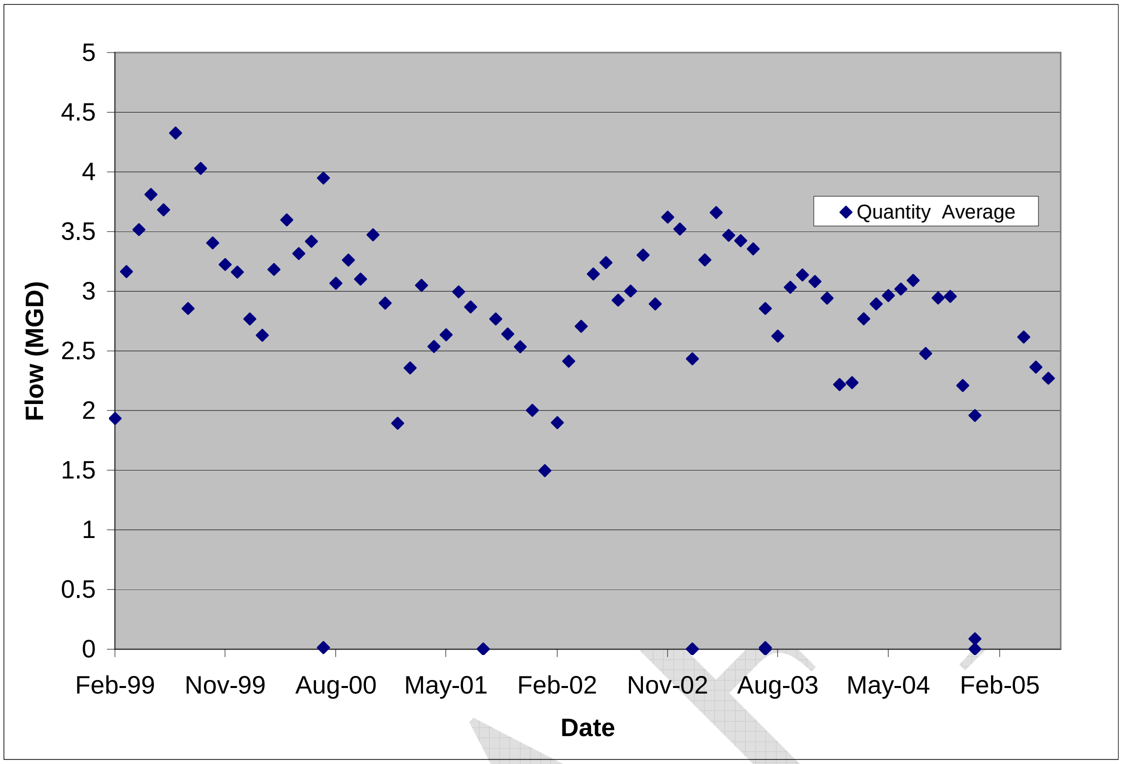


Figure A-19: Burlington Industries LCC Hurt Plant Flow Values

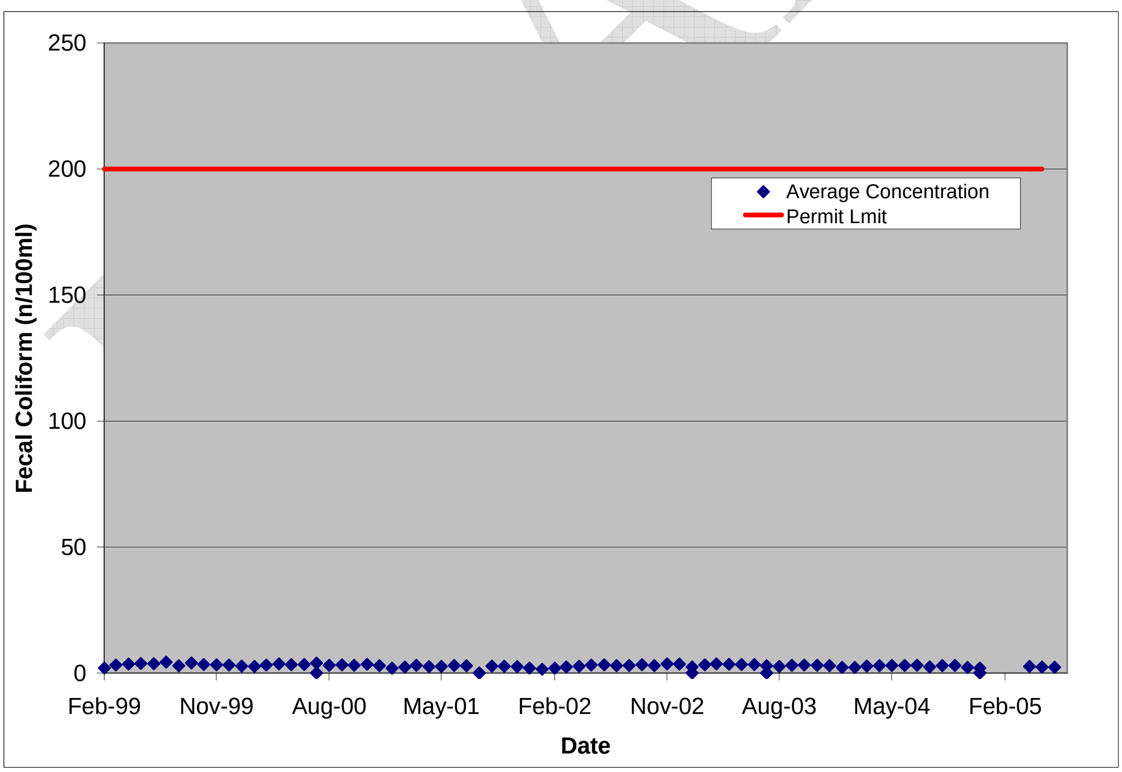


Figure A-20: Burlington Industries LCC Hurt Plant Fecal Coliform Concentrations

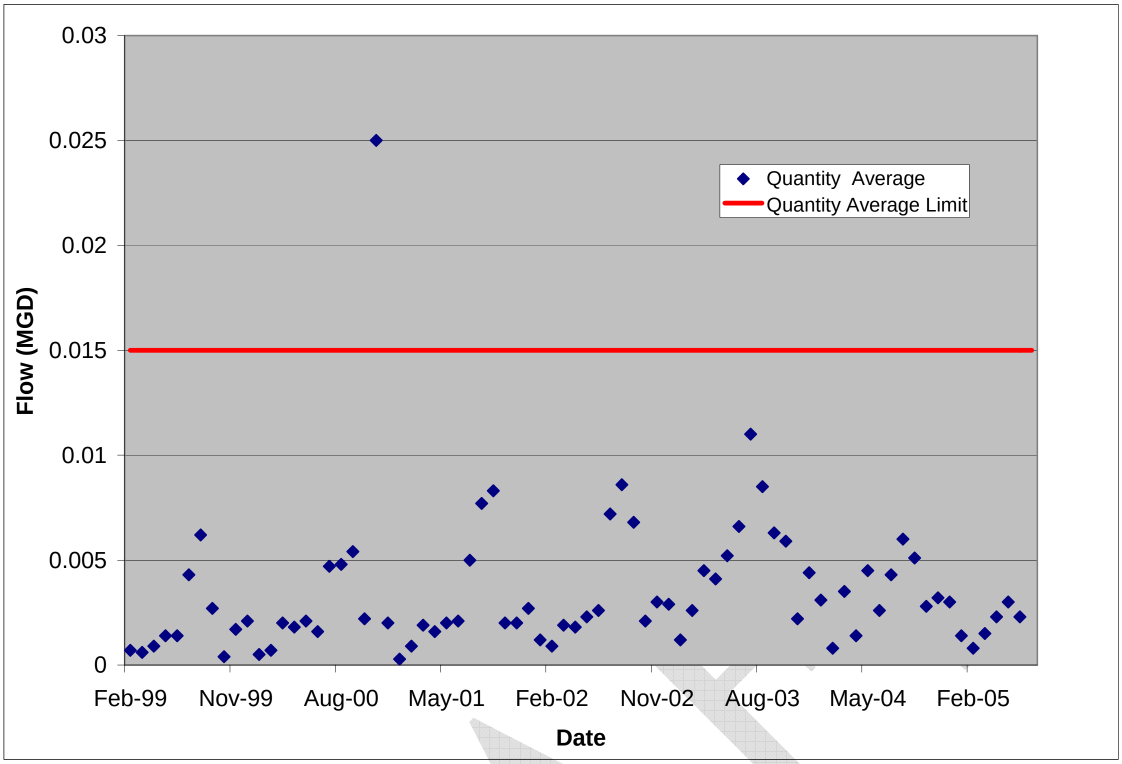


Figure A-21: Camp Jaycees STP Flow Values

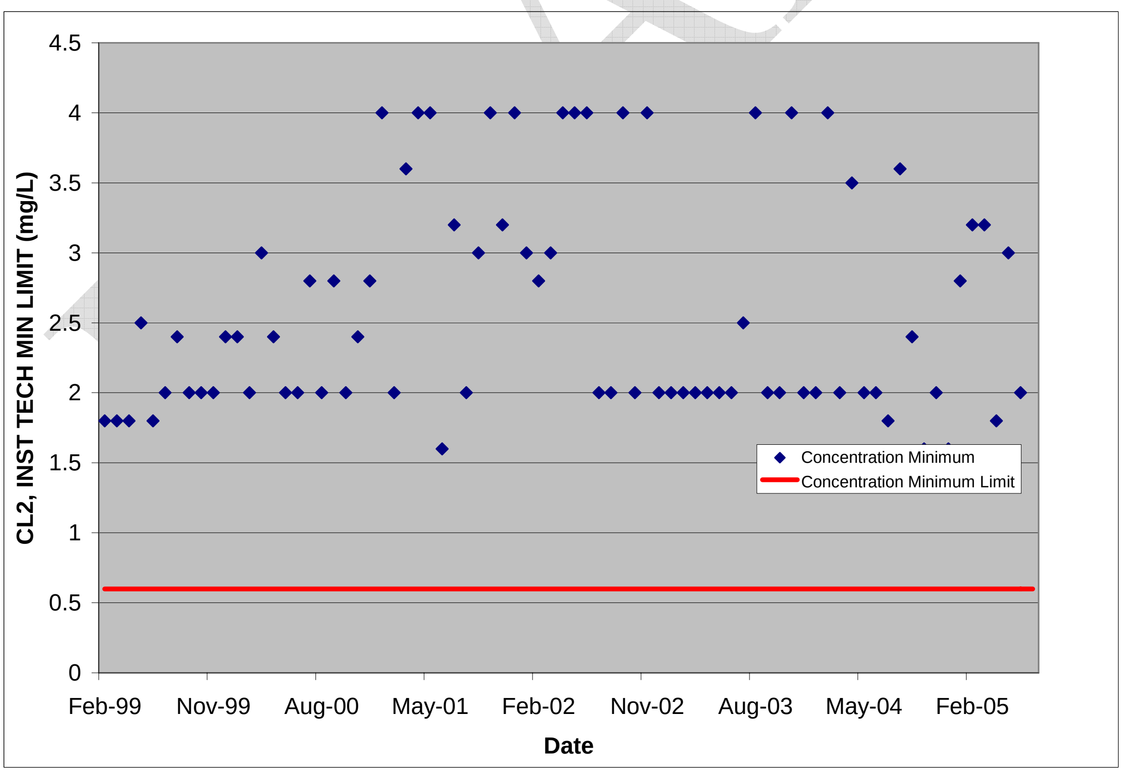


Figure A-22: Camp Jaycees STP Cl_2 Concentrations

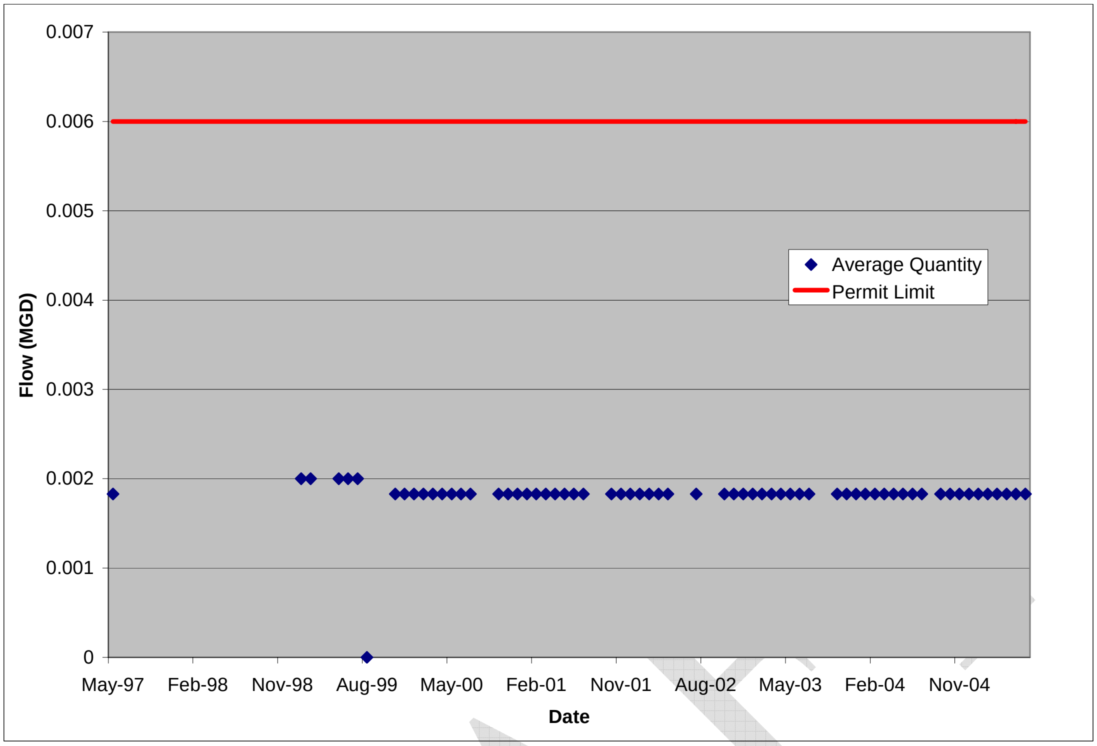


Figure A-23: Charlotte County School Bacon District Elementary Flow Values

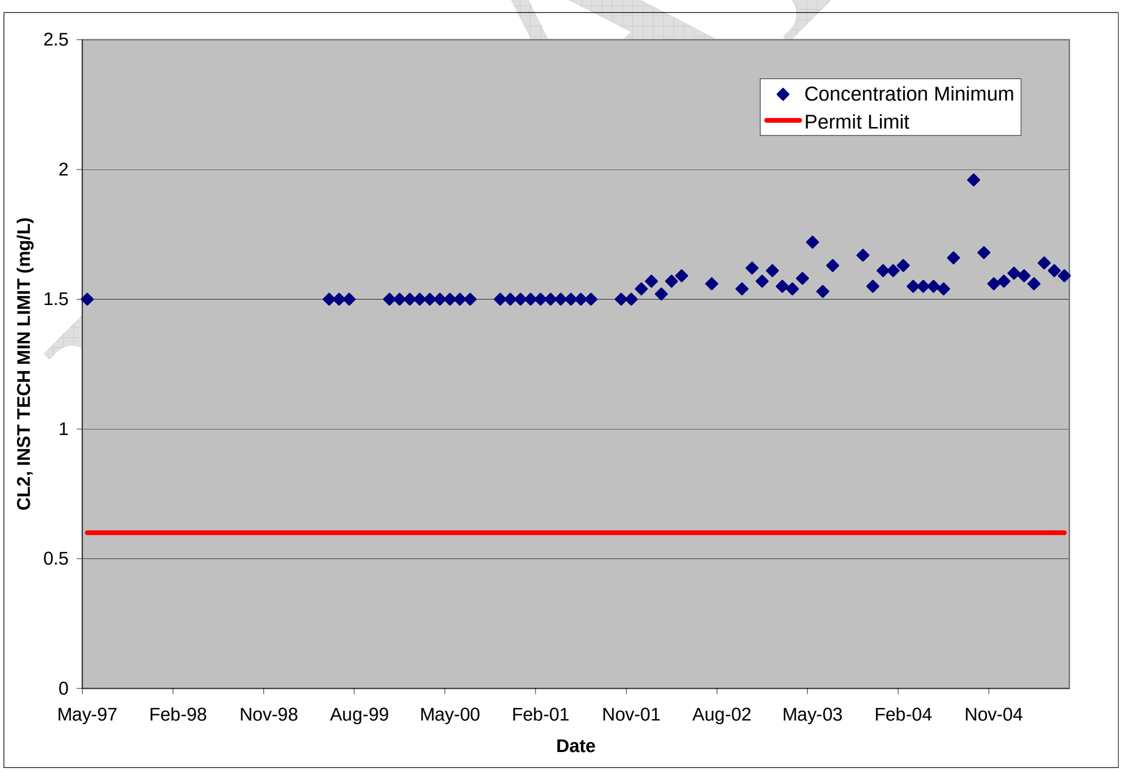


Figure A-24: Charlotte County School Bacon District Elementary Cl2 Concentrations

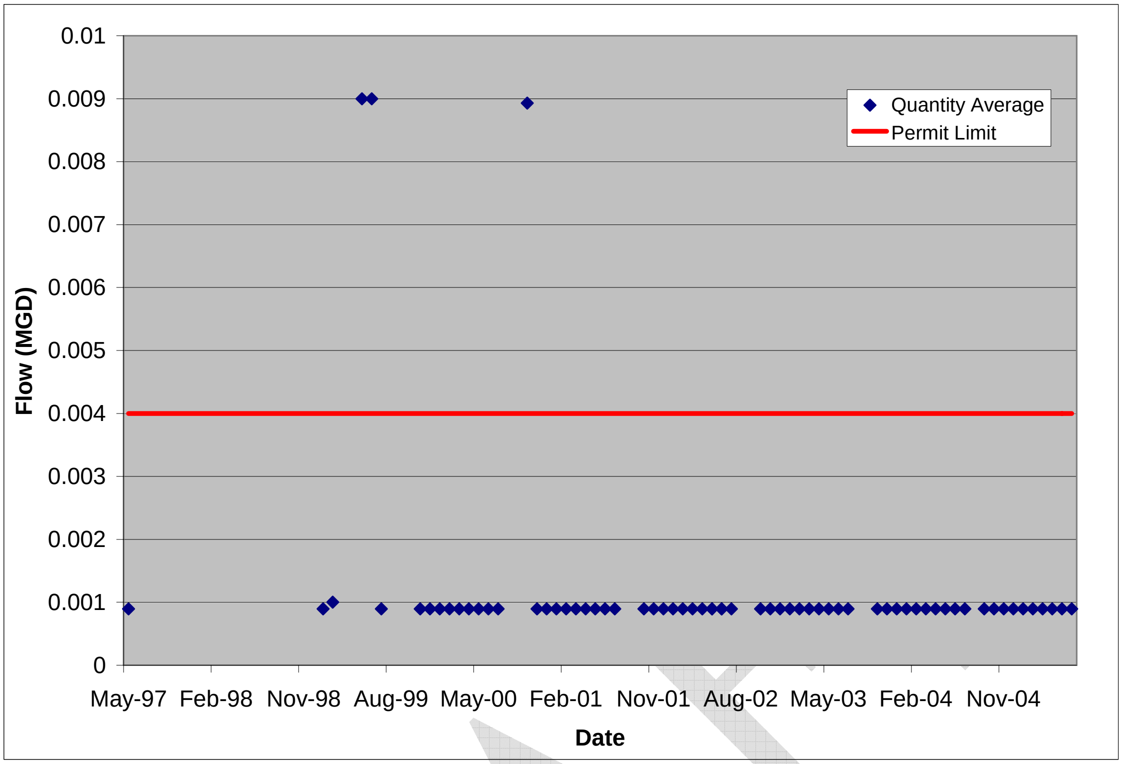


Figure A-25: Charlotte County School Jeffress Elementary Flow Values

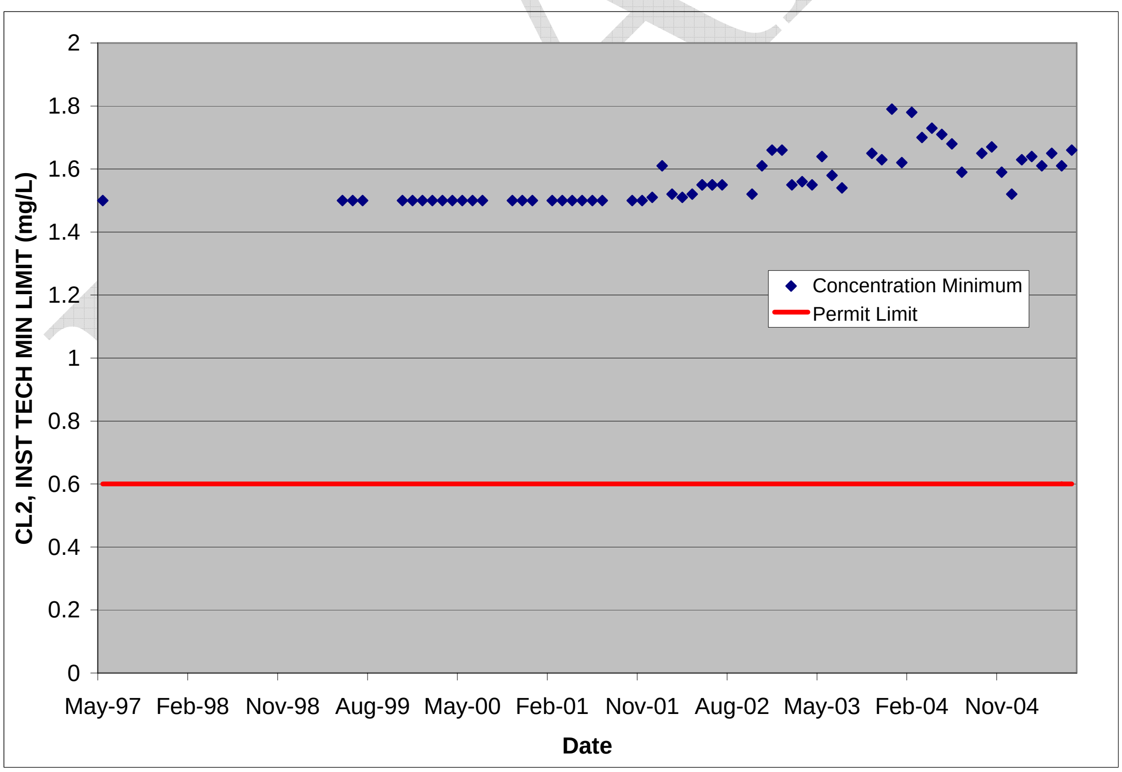


Figure A-26: Charlotte County School Jeffress Elementary Cl_2 Concentrations

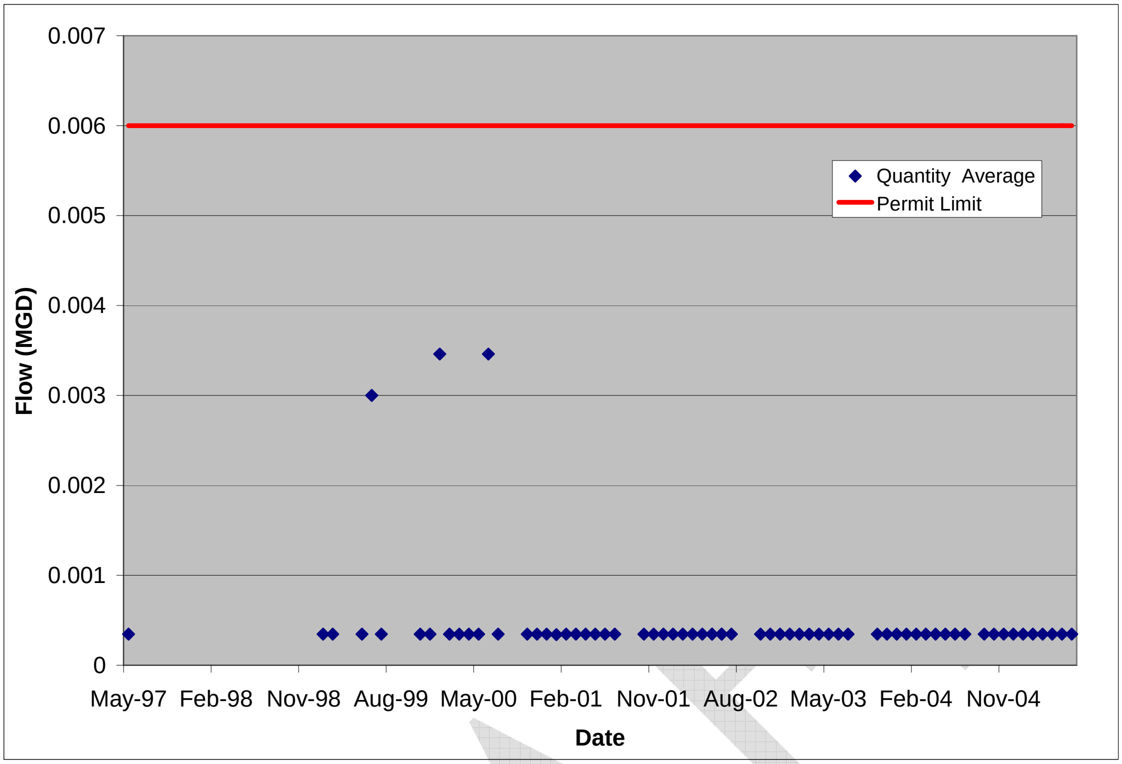


Figure A-27: Charlotte County School Phenix Elementary Flow Values

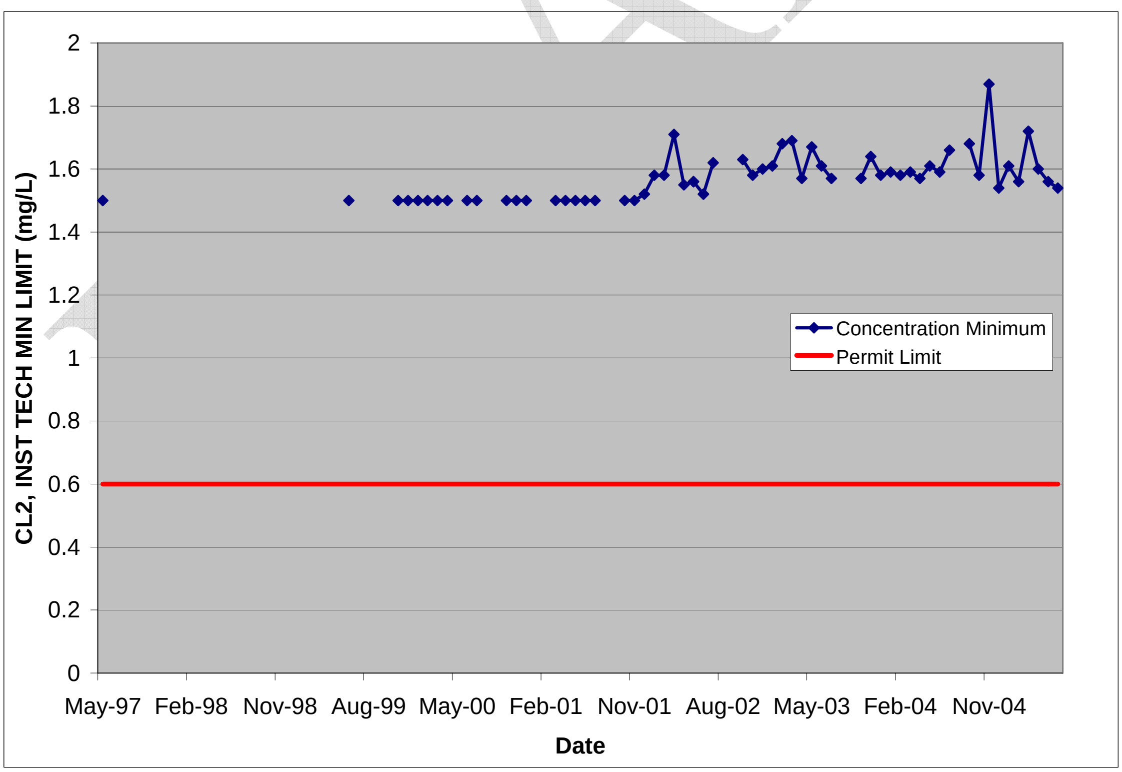


Figure A-28: Charlotte County School Phenix Elementary Cl_2 Concentrations

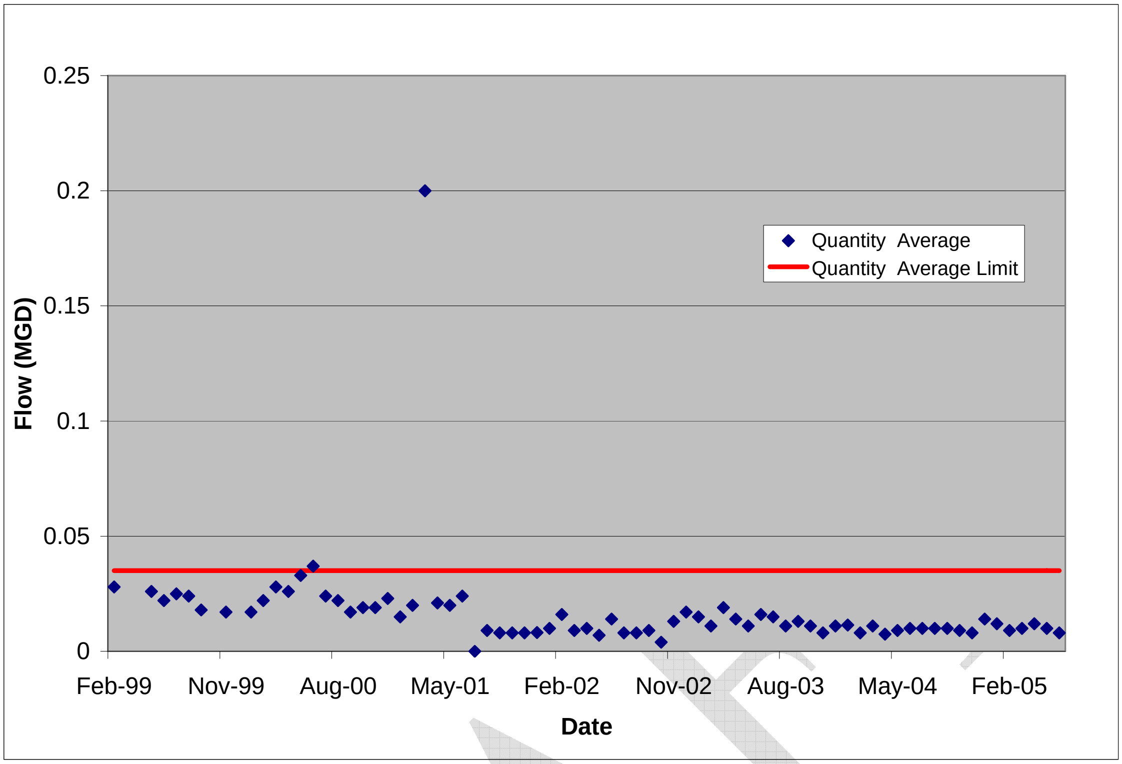


Figure A-29: Clover WWTP Flow Values

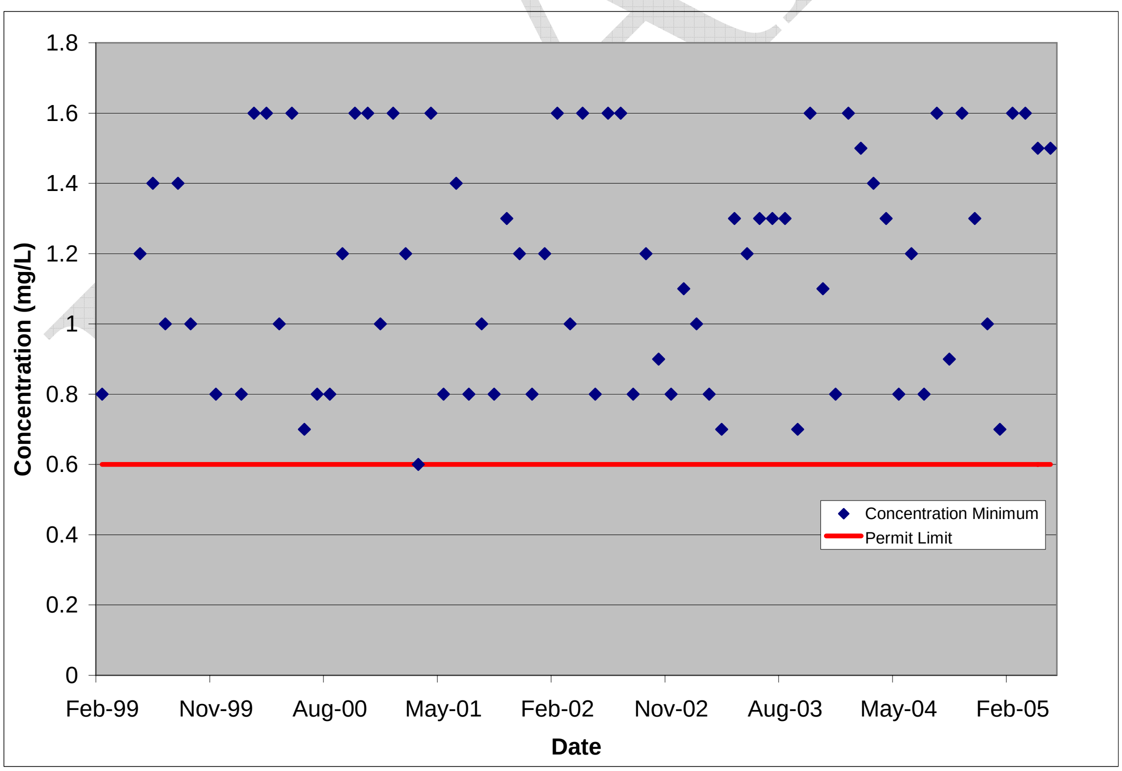


Figure A-30: Clover WWTP Cl_2 Concentrations

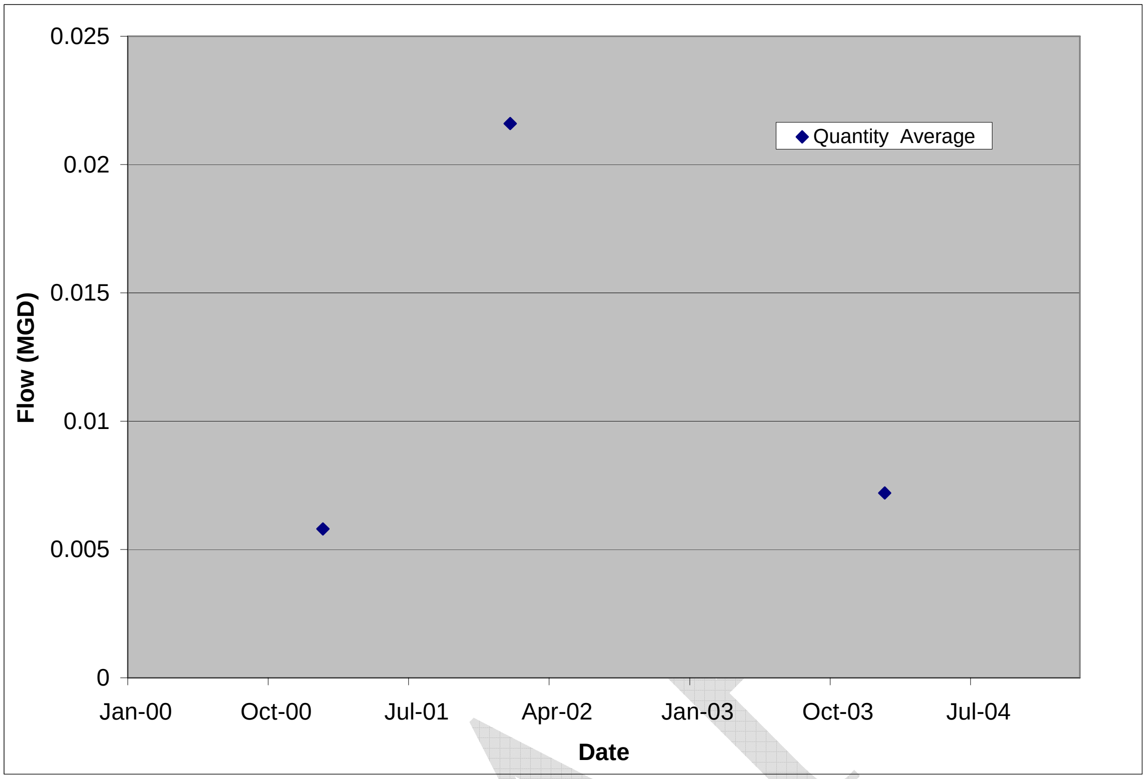


Figure A-31: Colonial Pipeline Co – Outfall 1 Flow Values

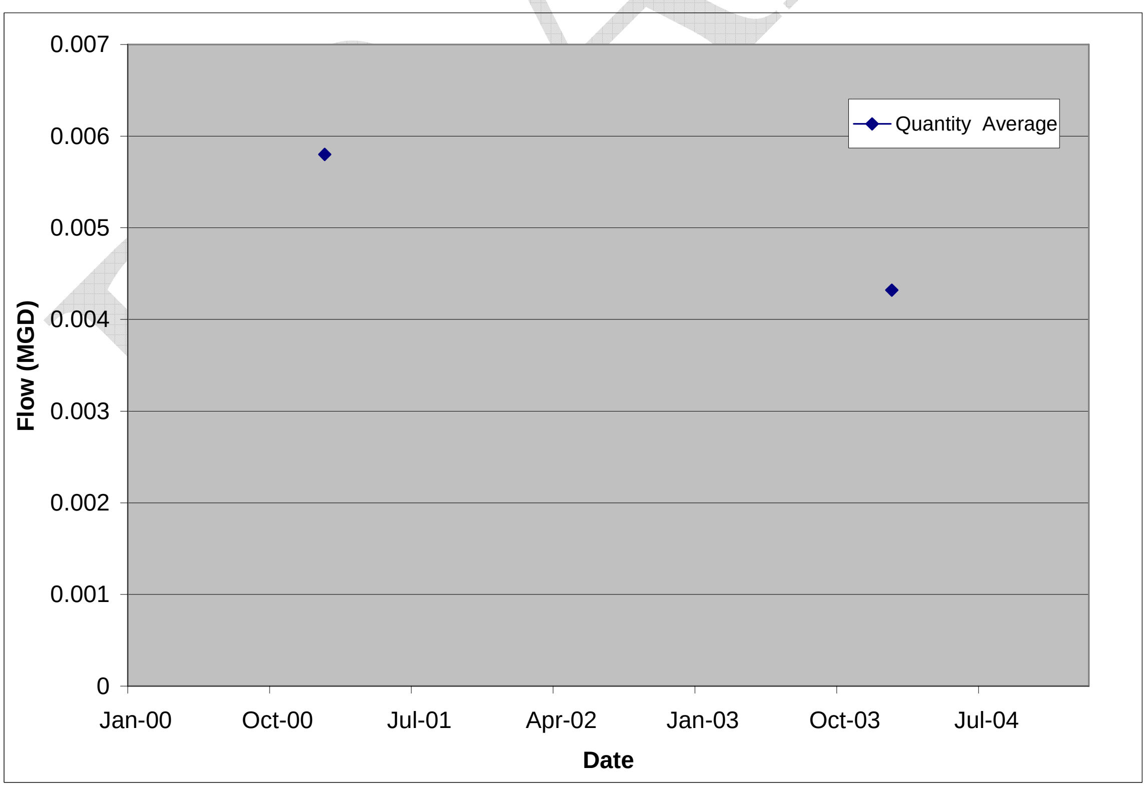


Figure A-32: Colonial Pipeline Co – Outfall 101 Flow Values

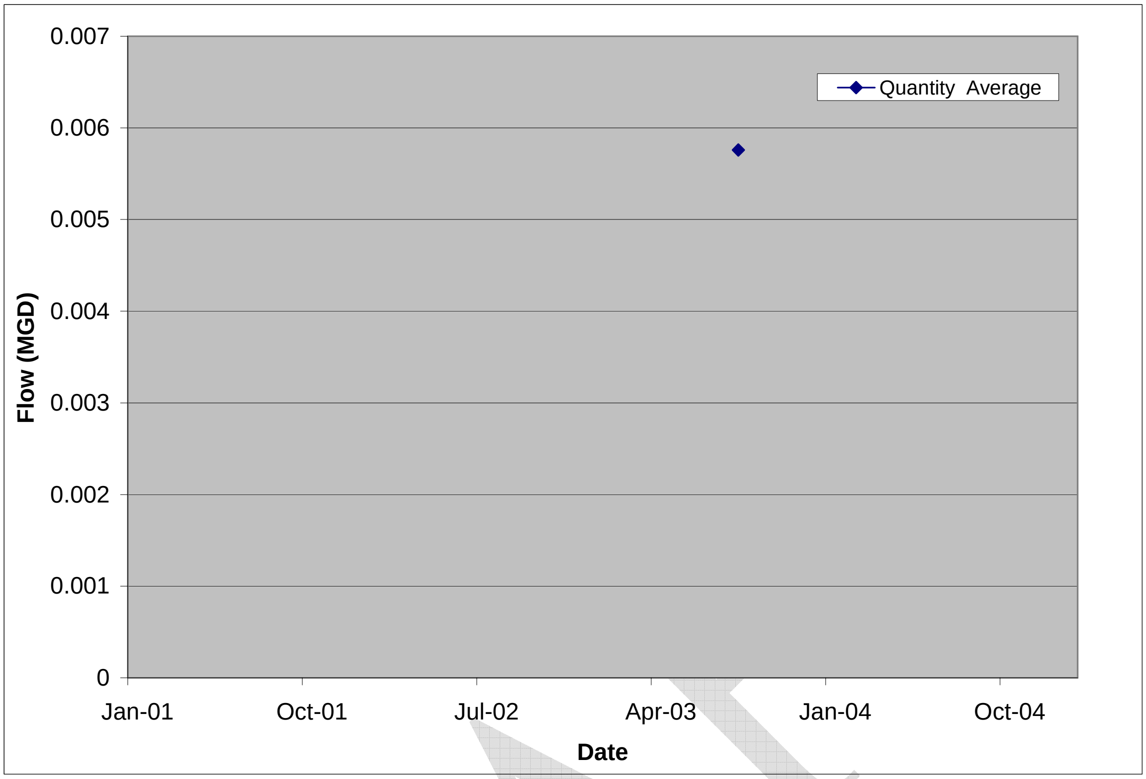


Figure A-33: Colonial Pipeline Hancock – Outfall 1 Flow Values

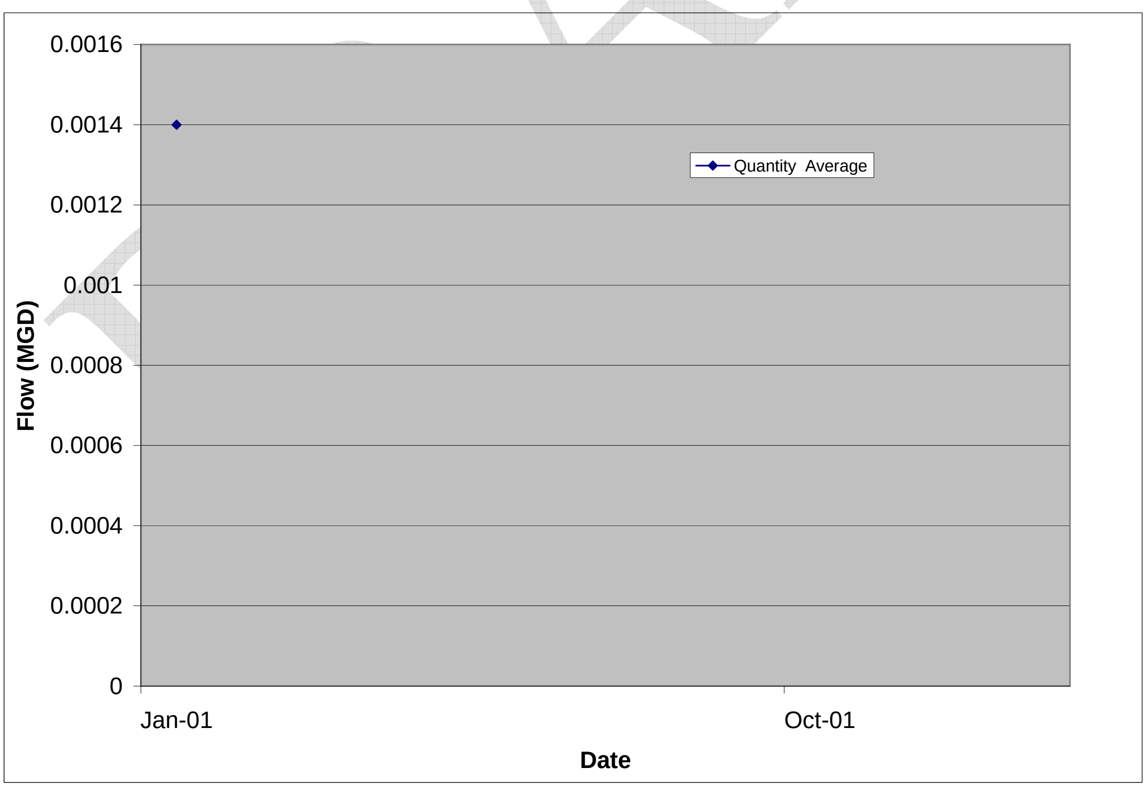


Figure A-34: Colonial Pipeline Hancock – Outfall 101 Flow Values

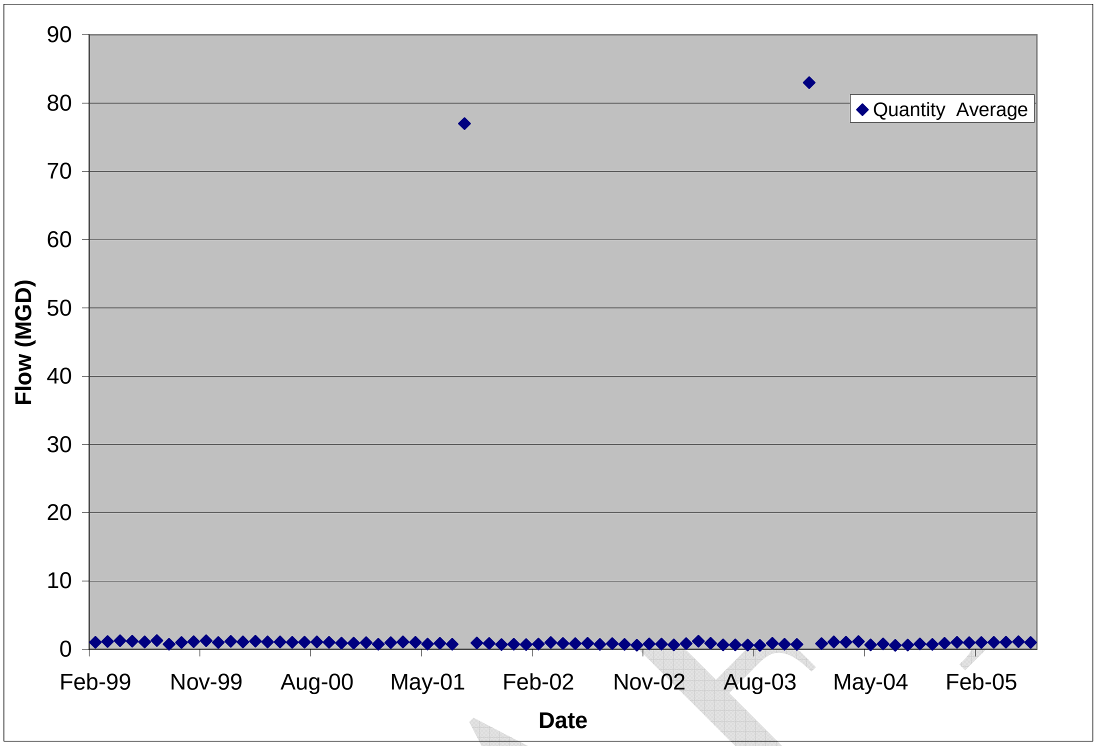


Figure A-35: Dan River Inc – Brookneal Flow Values

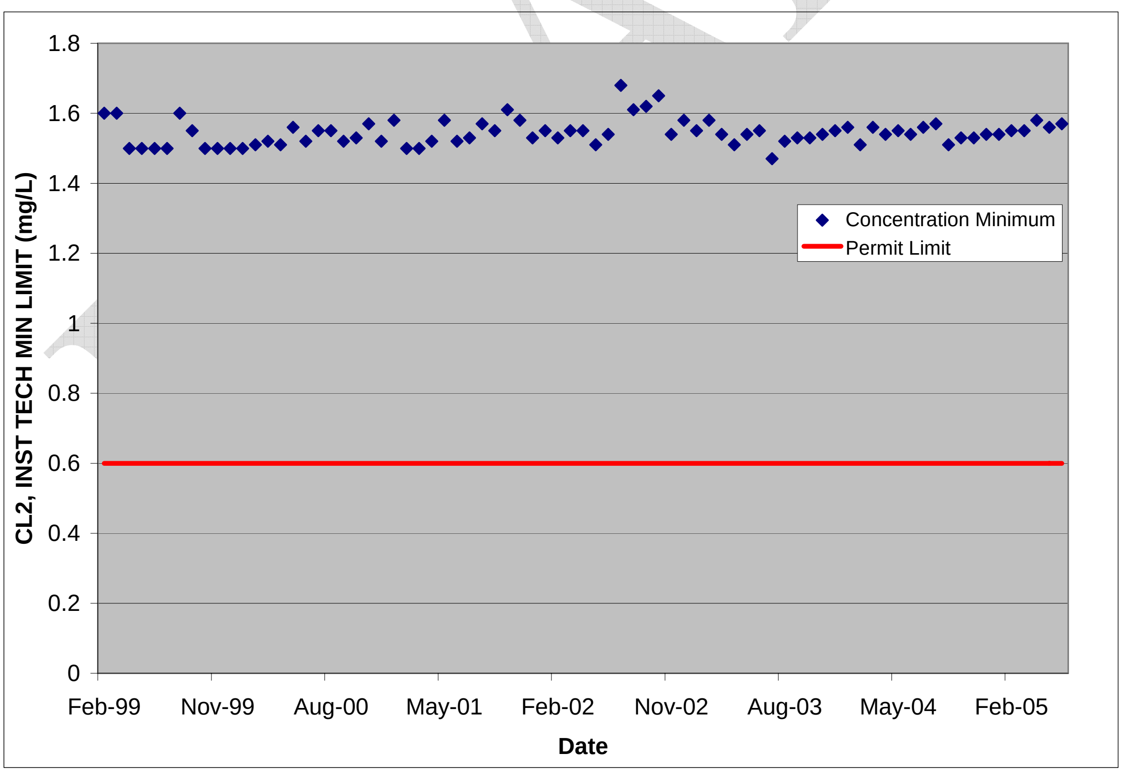


Figure A-36: Dan River Inc – Brookneal Cl_2 Concentrations

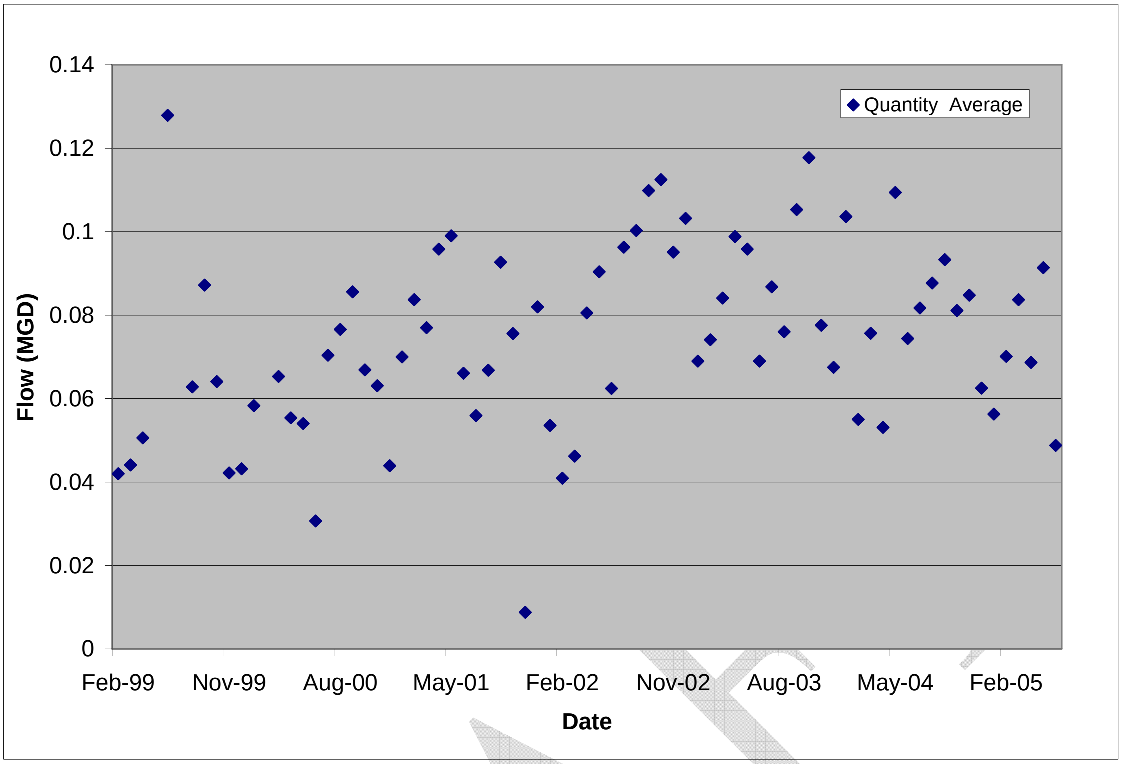


Figure A-37: Dominion – Altavista PS Outfall 1 Flow Values

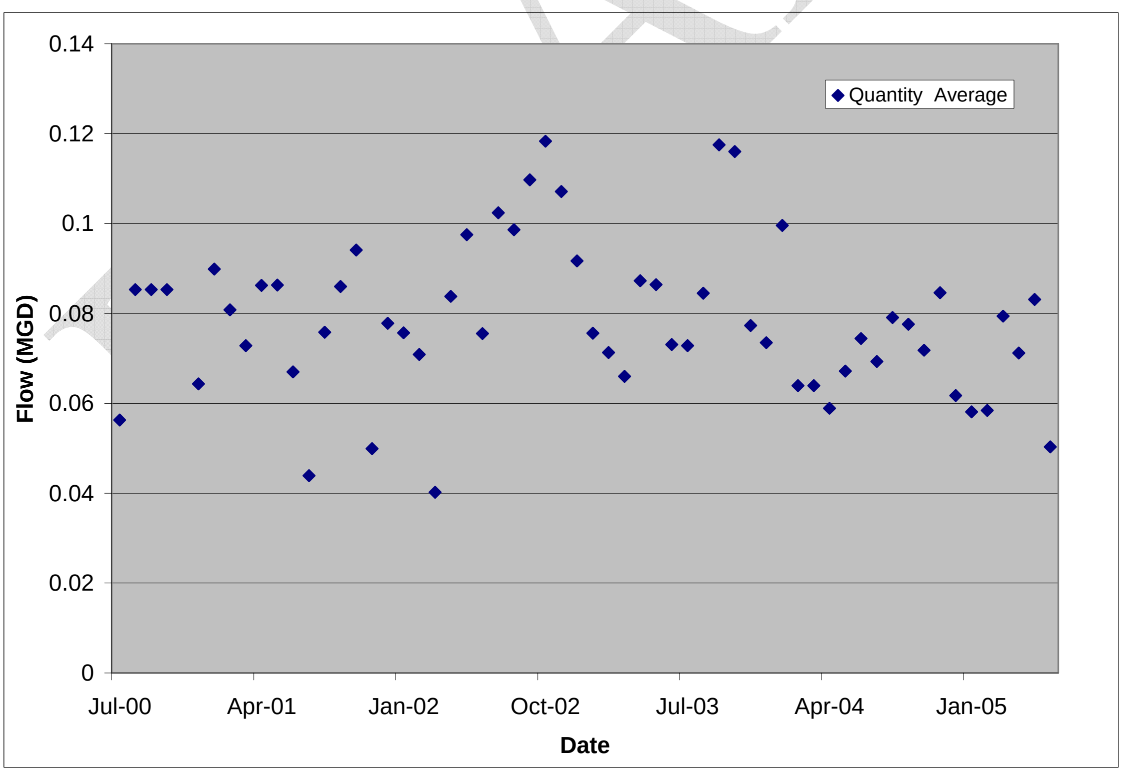


Figure A-38: Dominion – Altavista PS Outfall 101 Flow Values

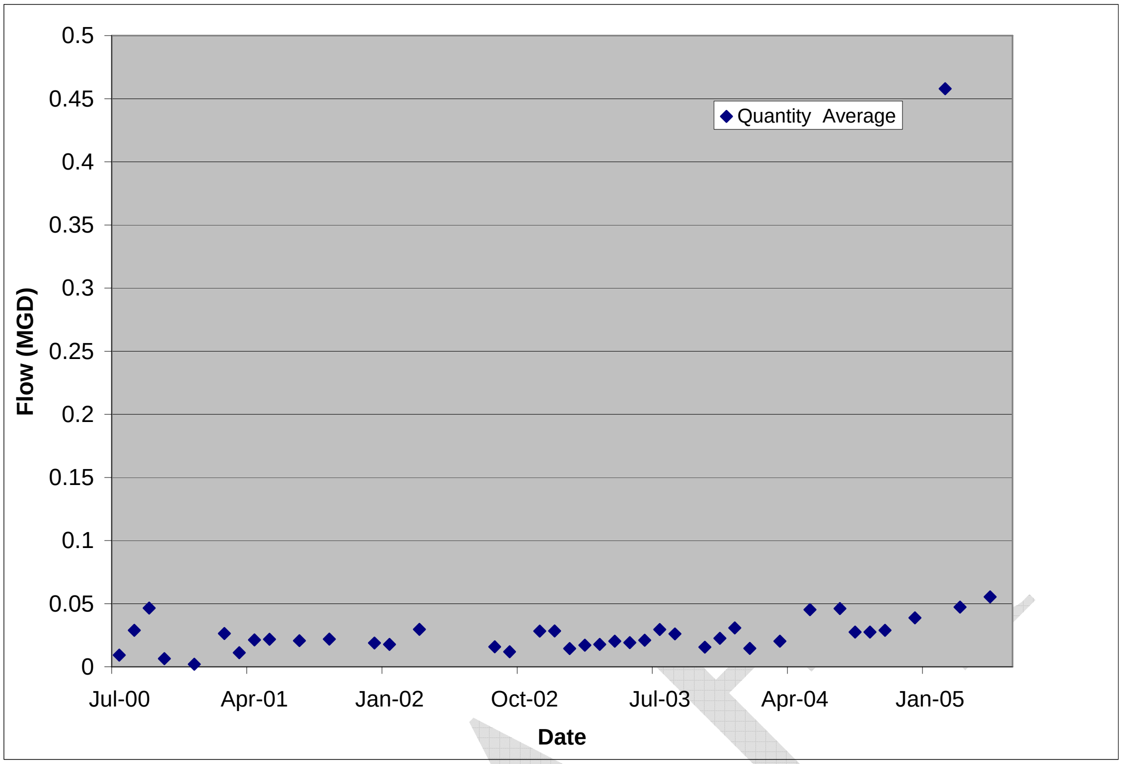


Figure A-39: Dominion – Altavista PS Outfall 103 Flow Values

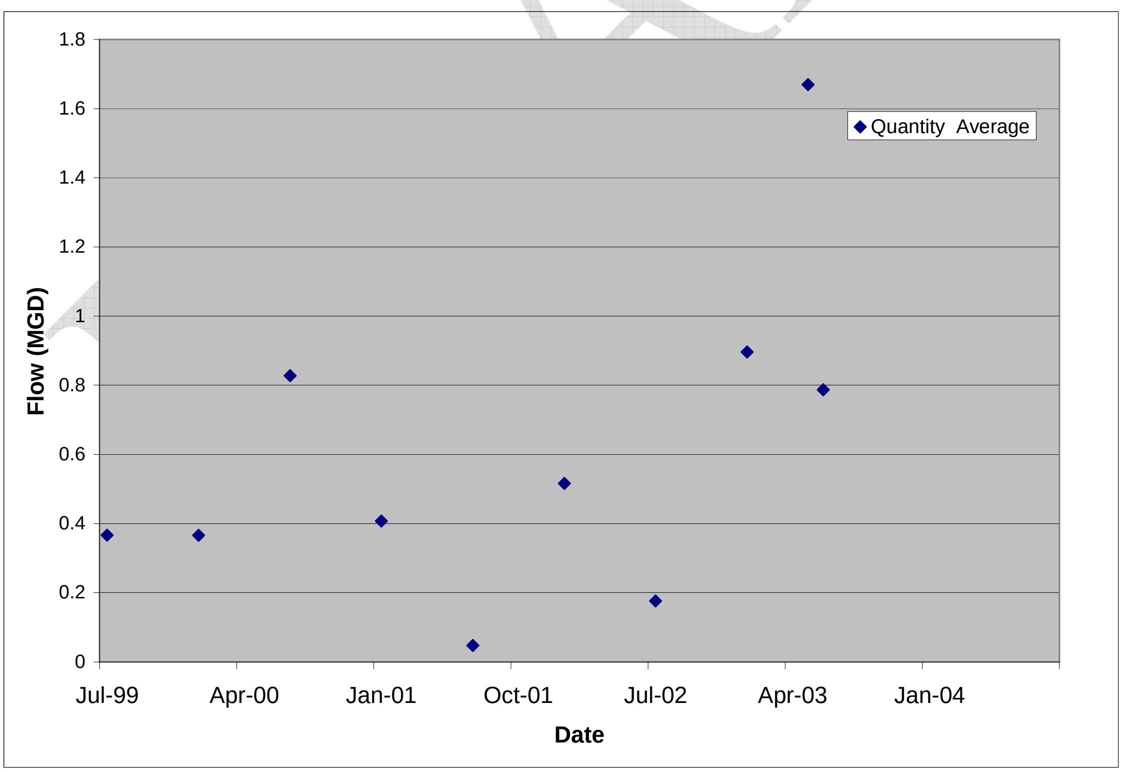


Figure A-40: Dominion - Altavista PS Outfall 900 Flow Values

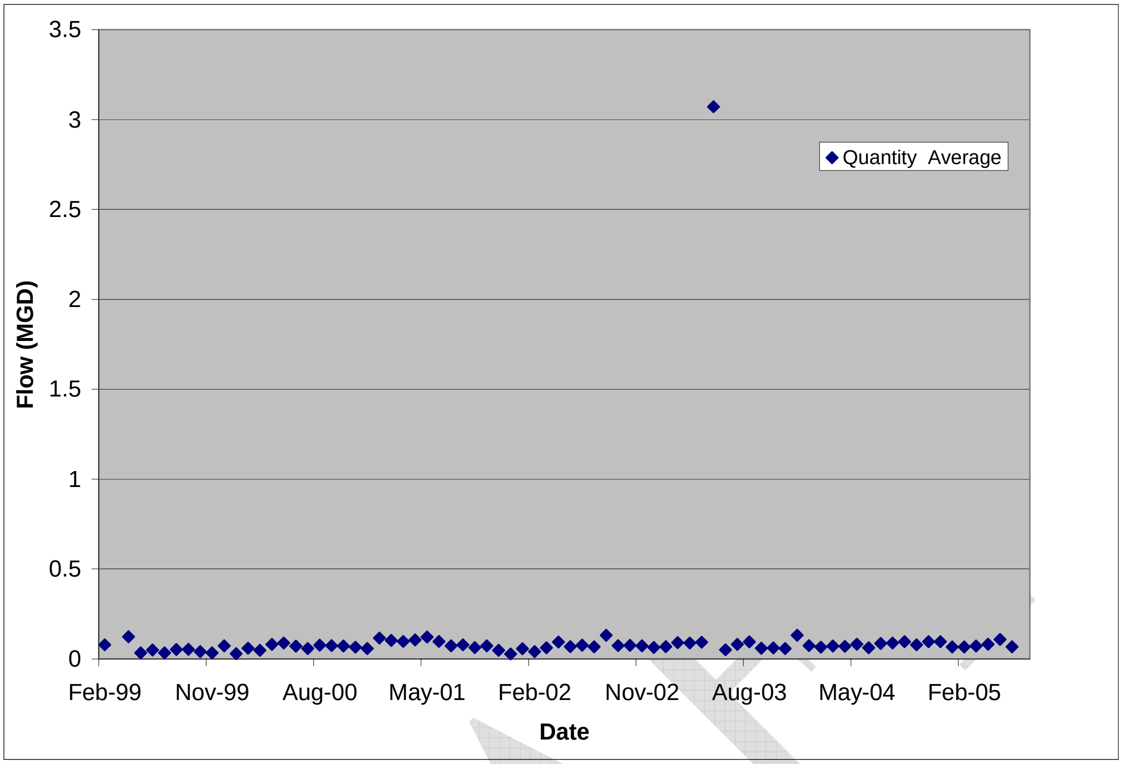


Figure A-41: Dominion Pittsylvania PS – Outfall 1 Flows

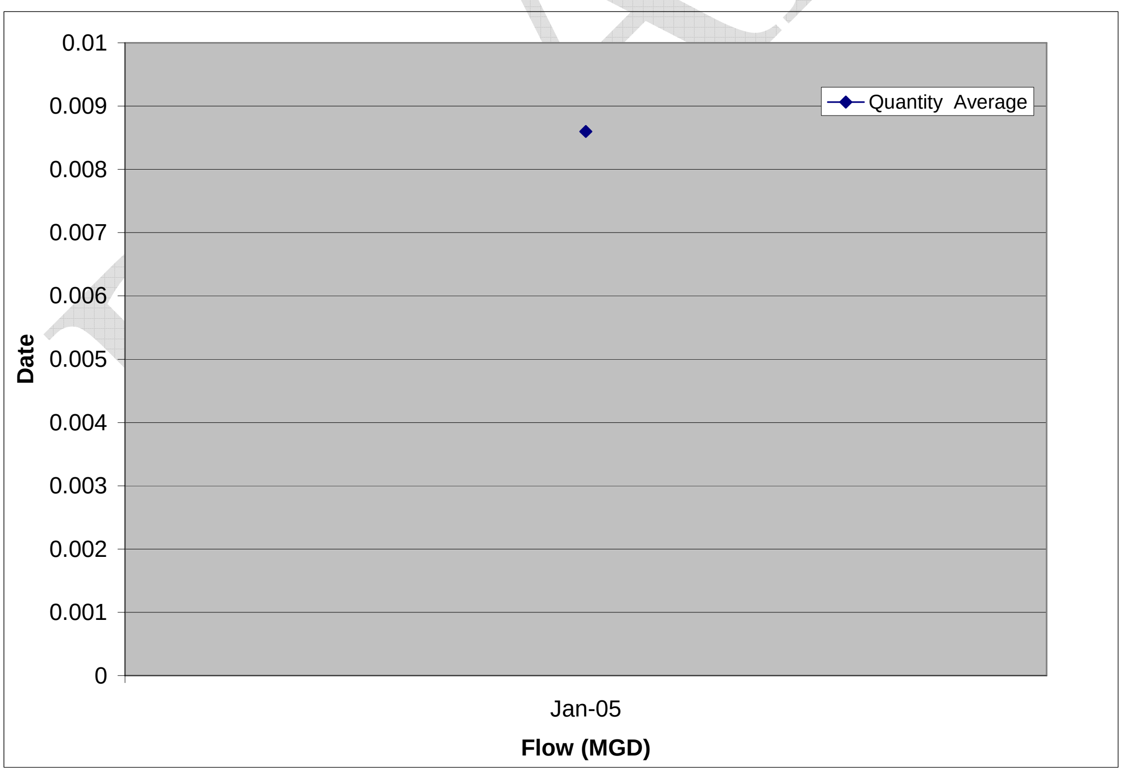


Figure A-42: Dominion Pittsylvania PS – Outfall 2Flows

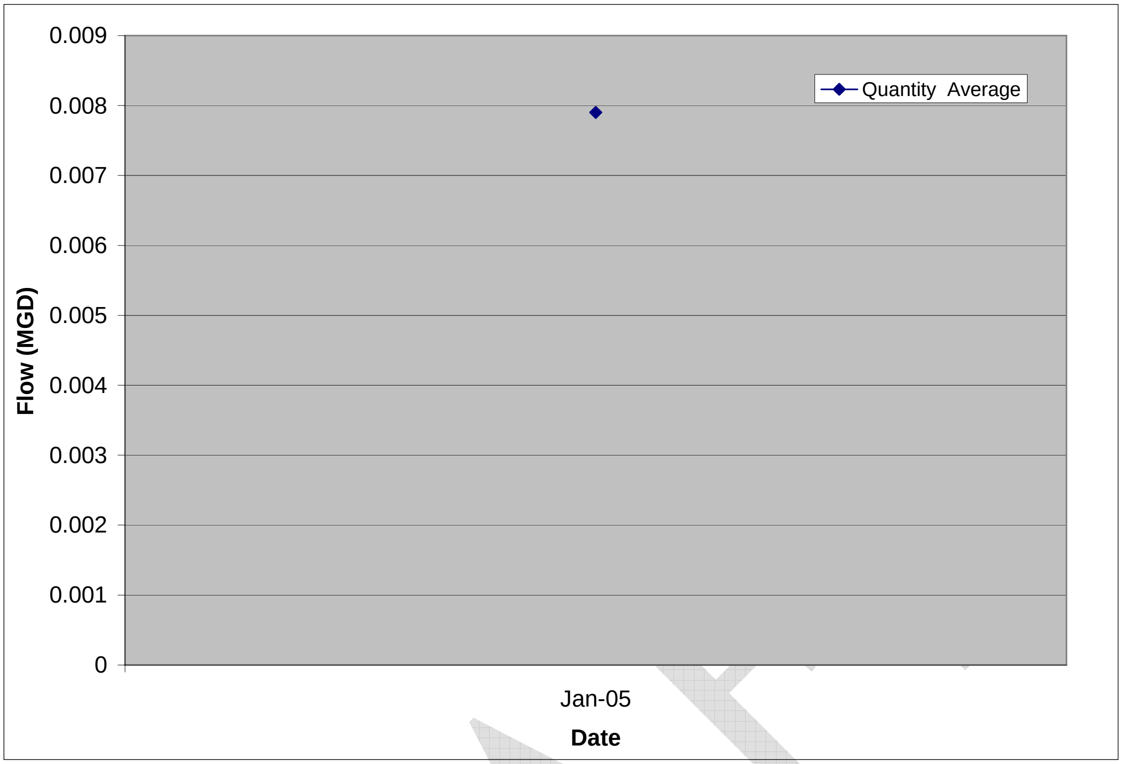


Figure A-43: Dominion Pittsylvania PS – Outfall 3 Flows

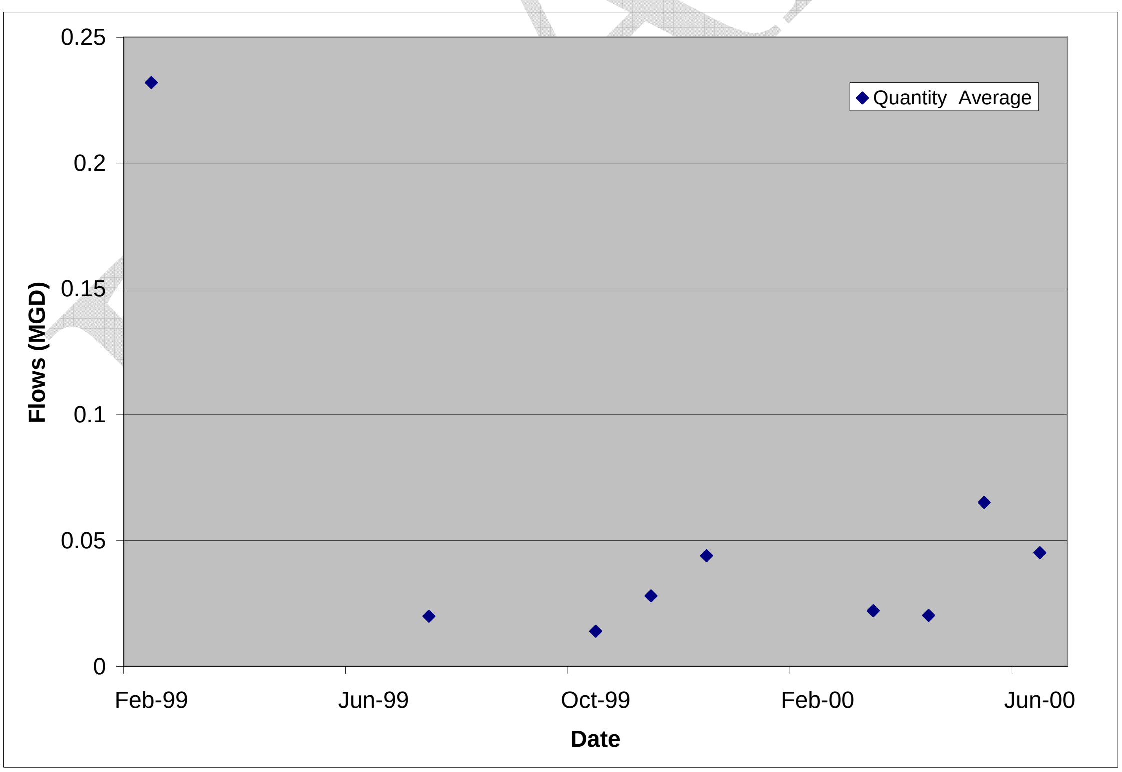


Figure A-44: Dominion Pittsylvania PS – Outfall 101 Flows

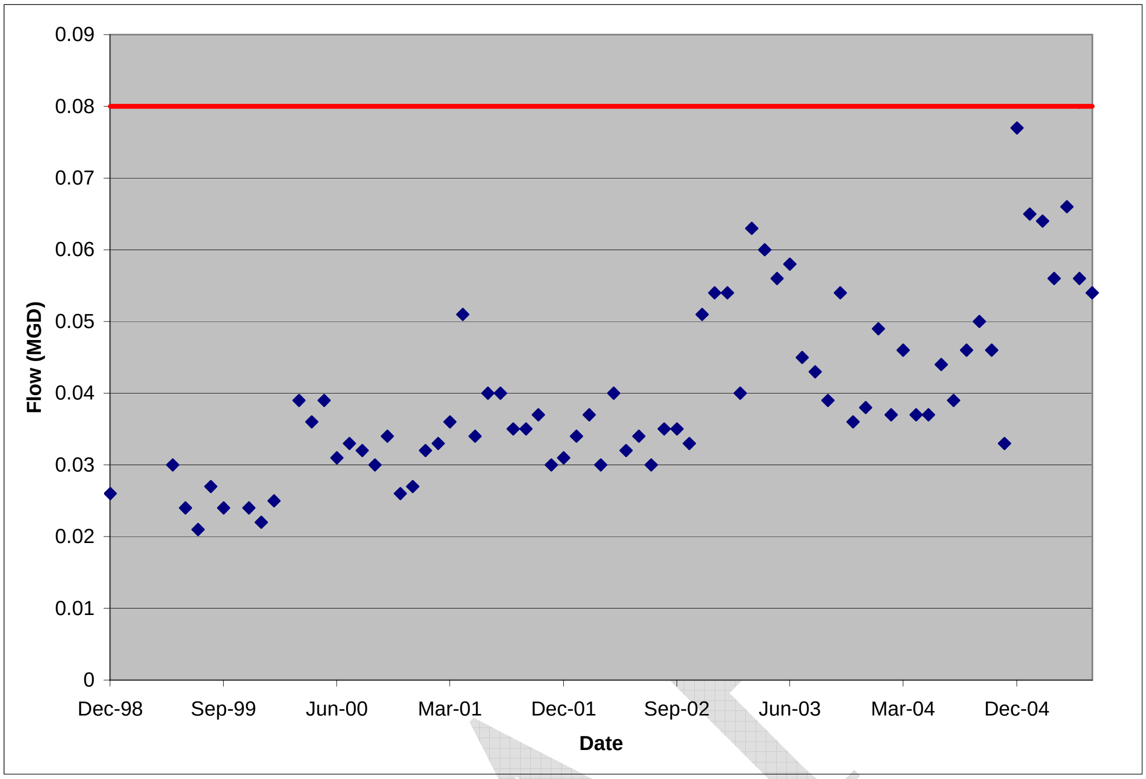


Figure A-45: Drakes Branch WWTP Flow Values

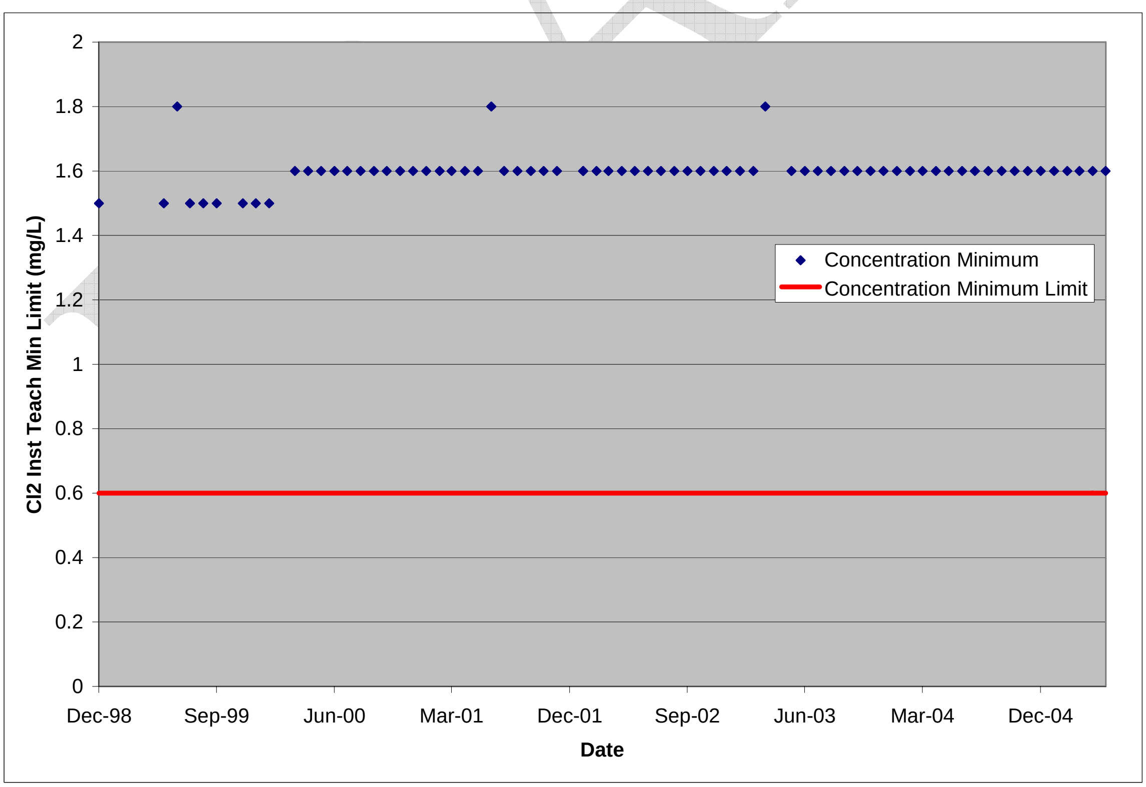


Figure A-46: Drakes Branch WWTP Cl2 Concentrations

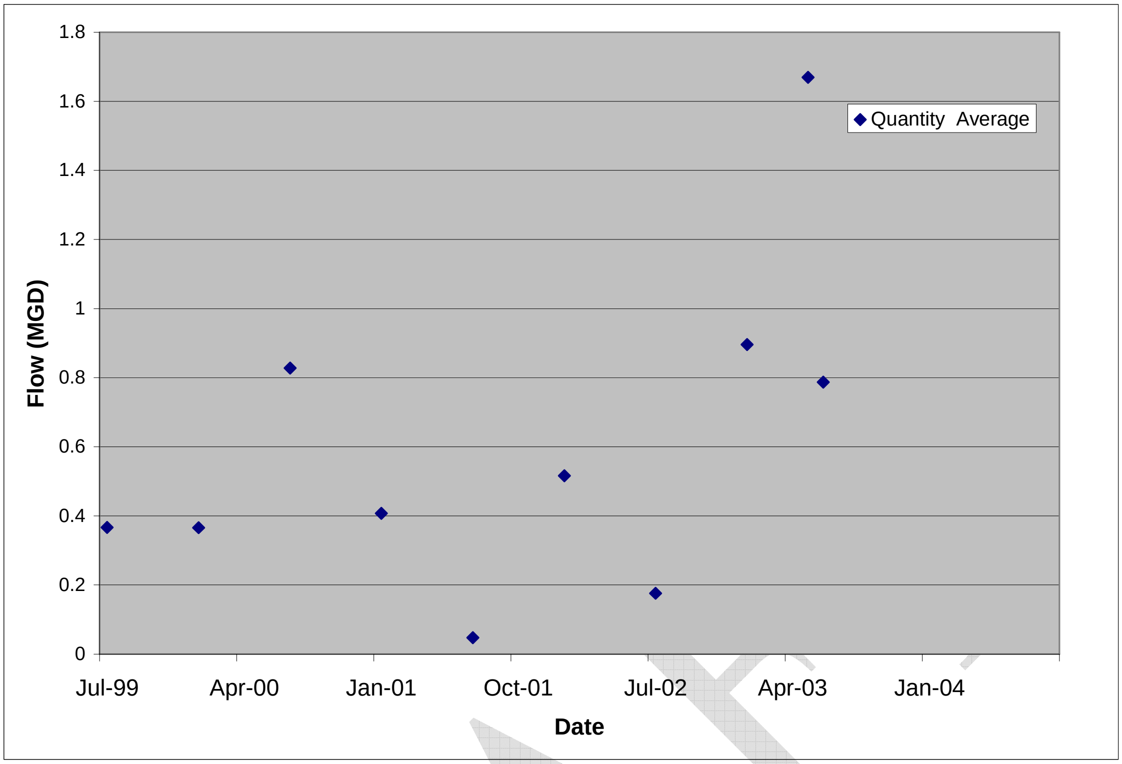


Figure A-47: Halifax Co School Clays Mill Elementary Flow Values

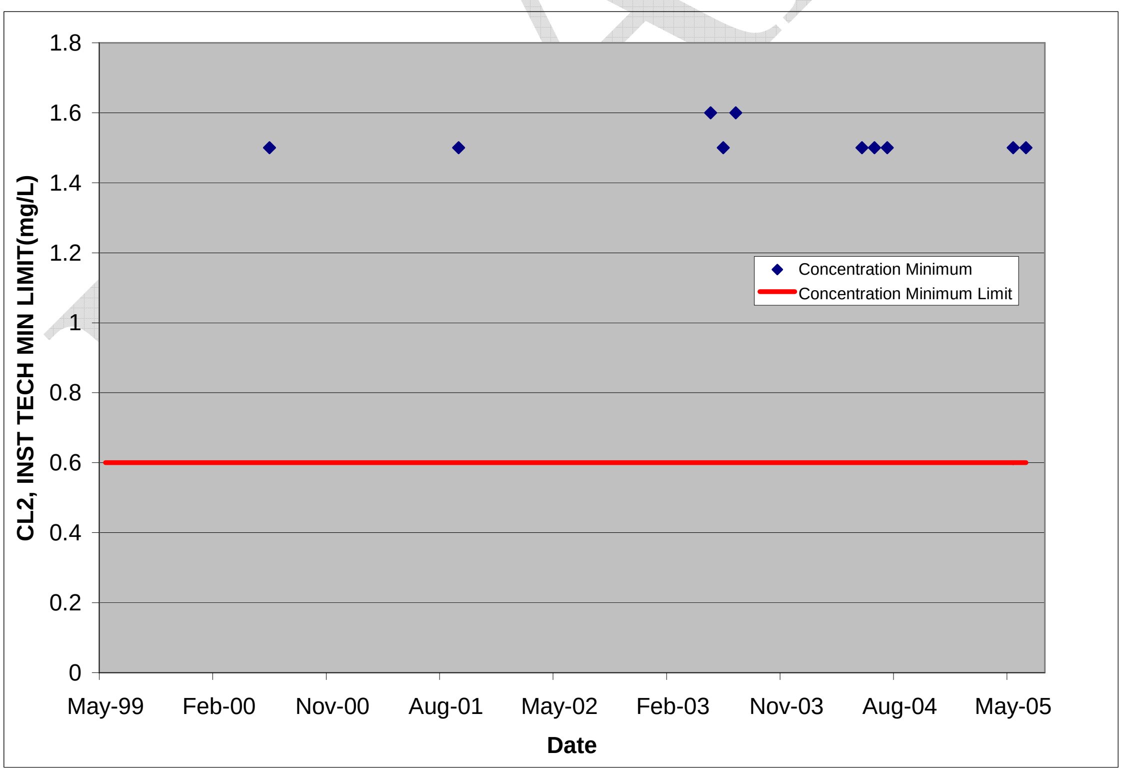


Figure A-48: Halifax Co School Clays Mill Elementary Cl_2 Concentrations

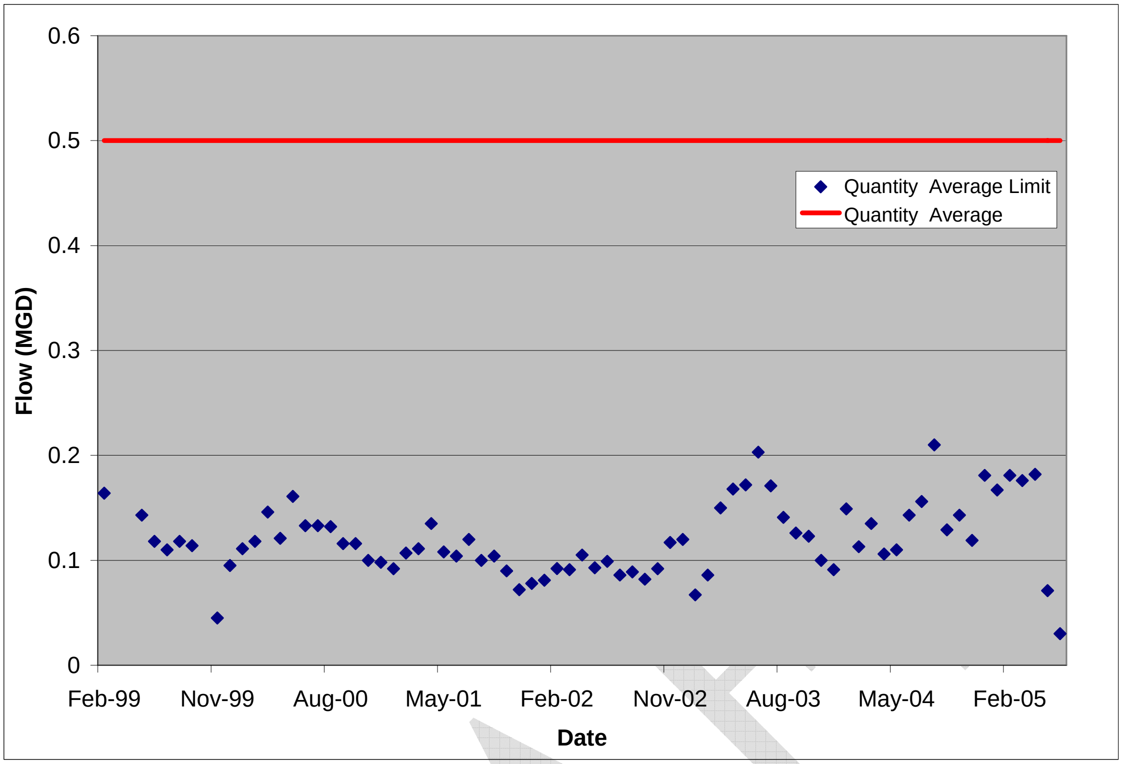


Figure A-49: Keysville WWTP Flow Values

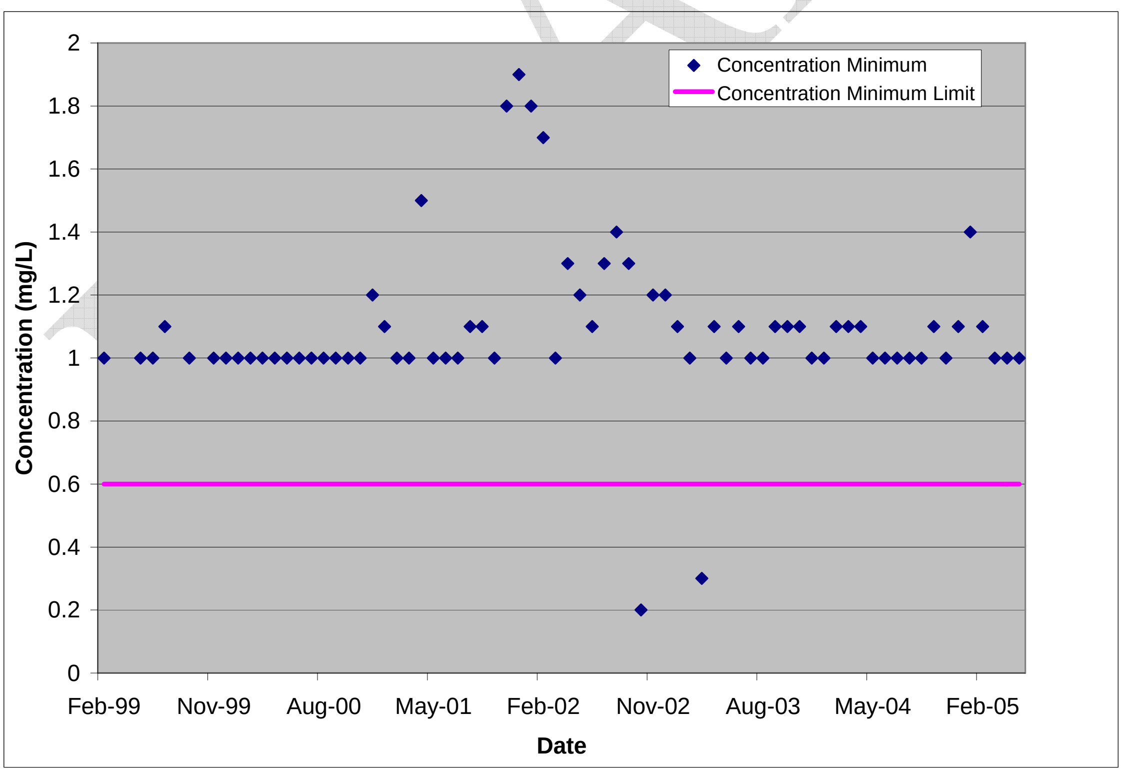


Figure A-50: Keysville WWTP Cl_2 Concentrations

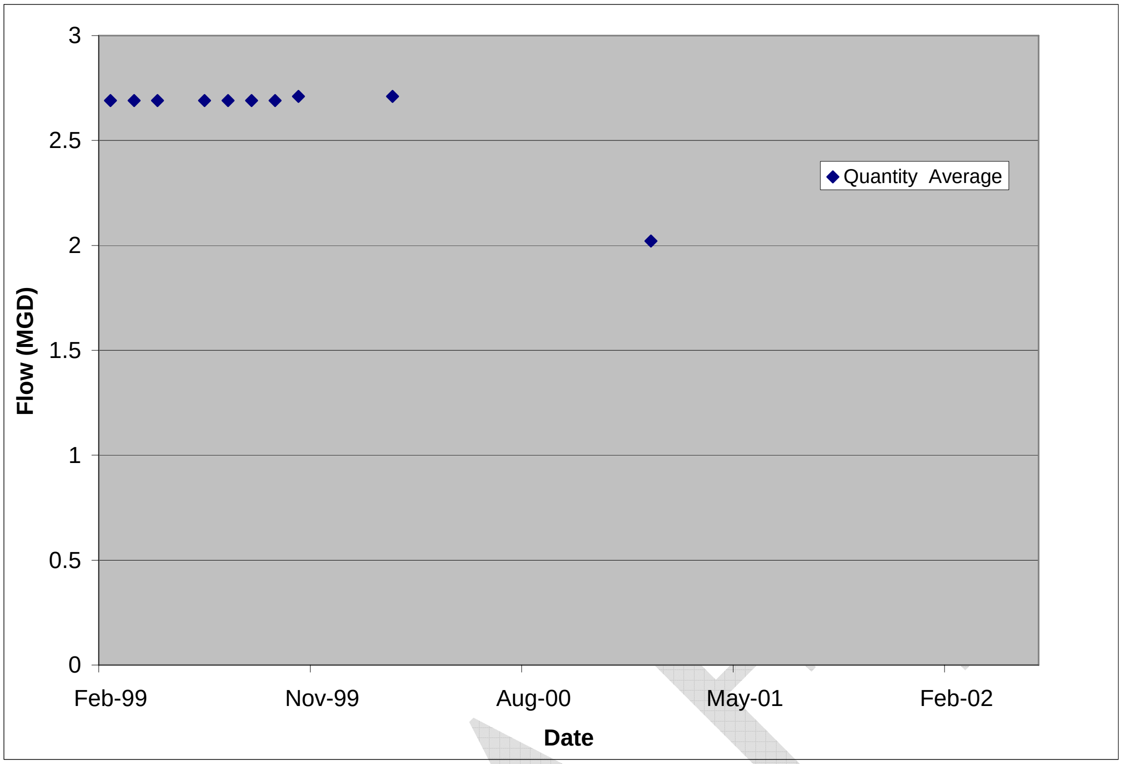


Figure A-51: Lane Furniture Industries Inc Outfall 1 Flow Values

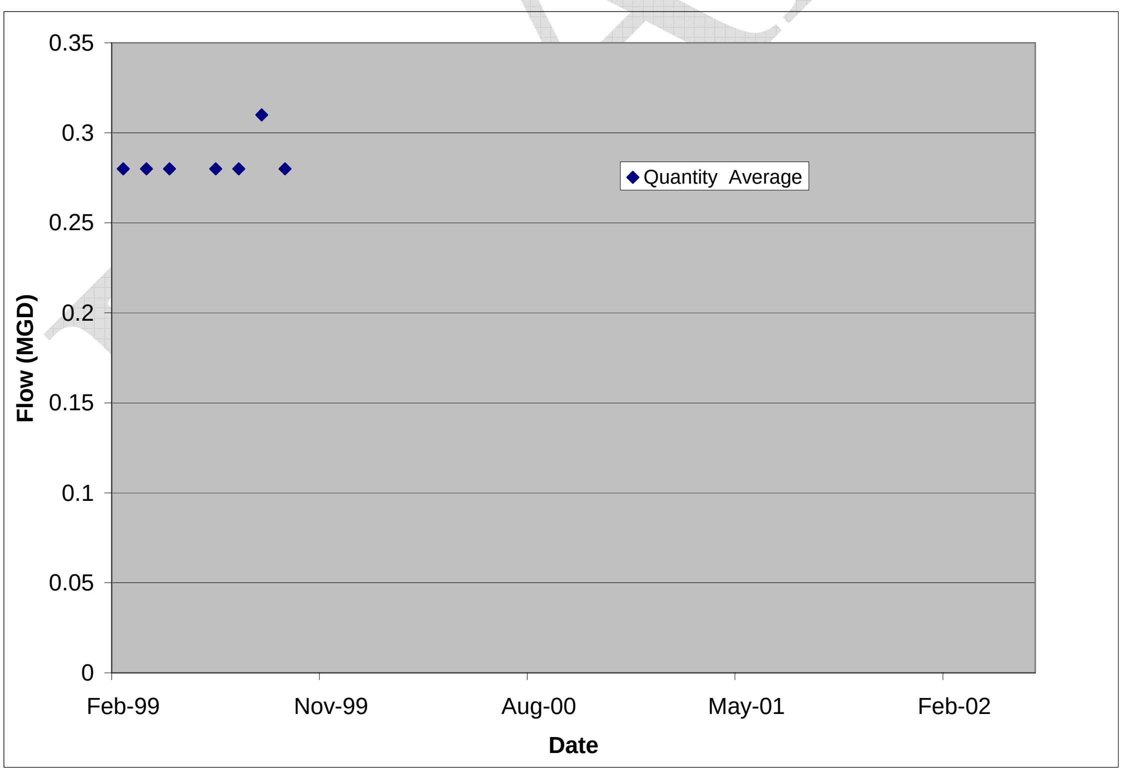


Figure A-52: Lane Furniture Industries Inc Outfall 3 Flow Values

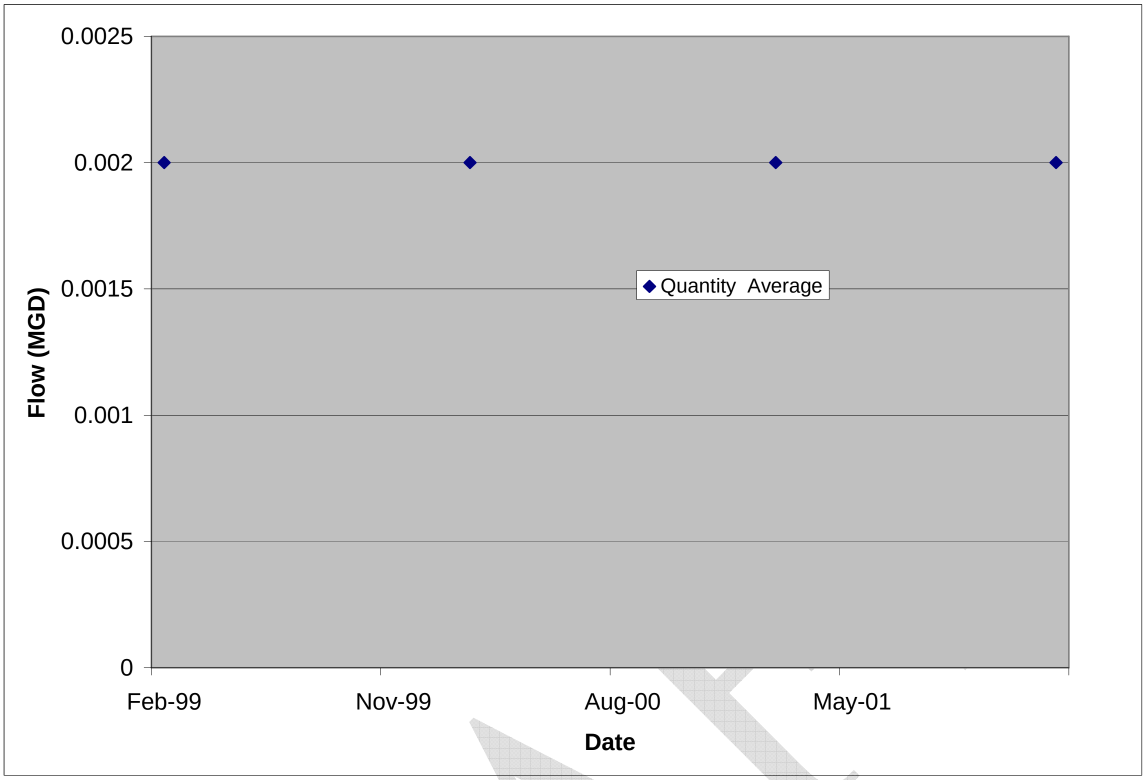


Figure A-53: Lane Furniture Industries Inc Outfall 4 Flow Values

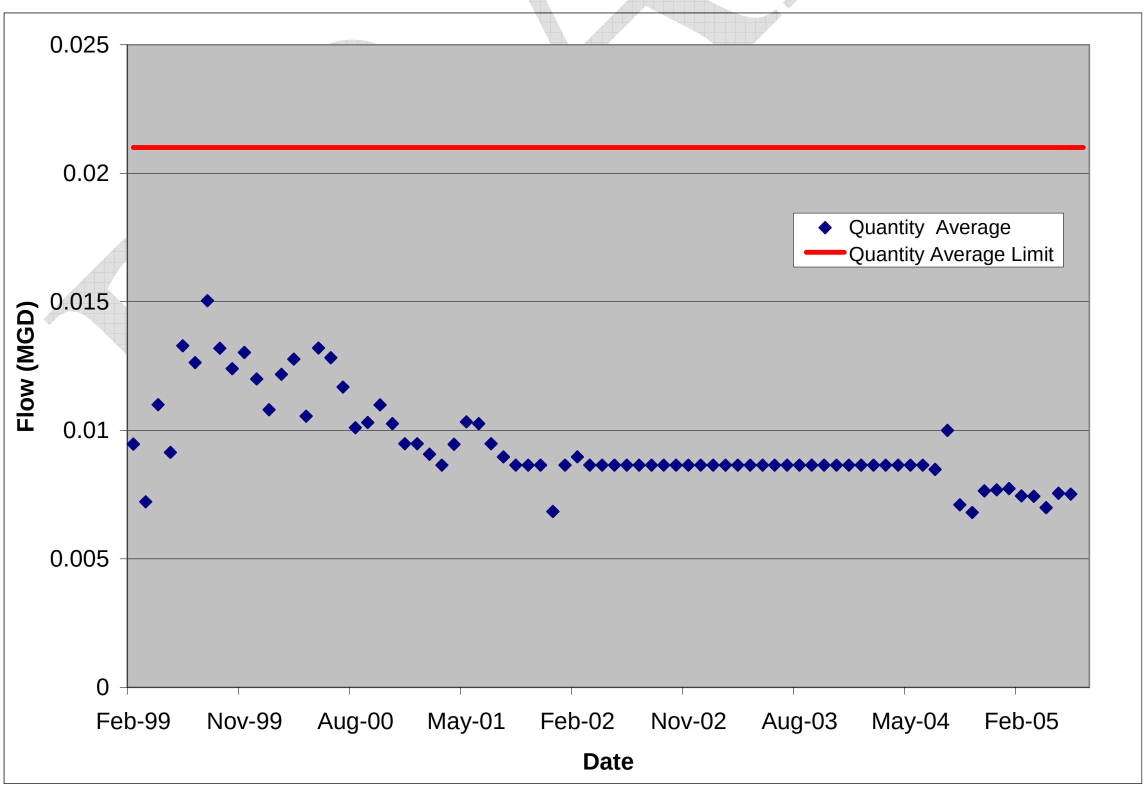


Figure A-54: Moneta Adult Detention Facility Flow Values

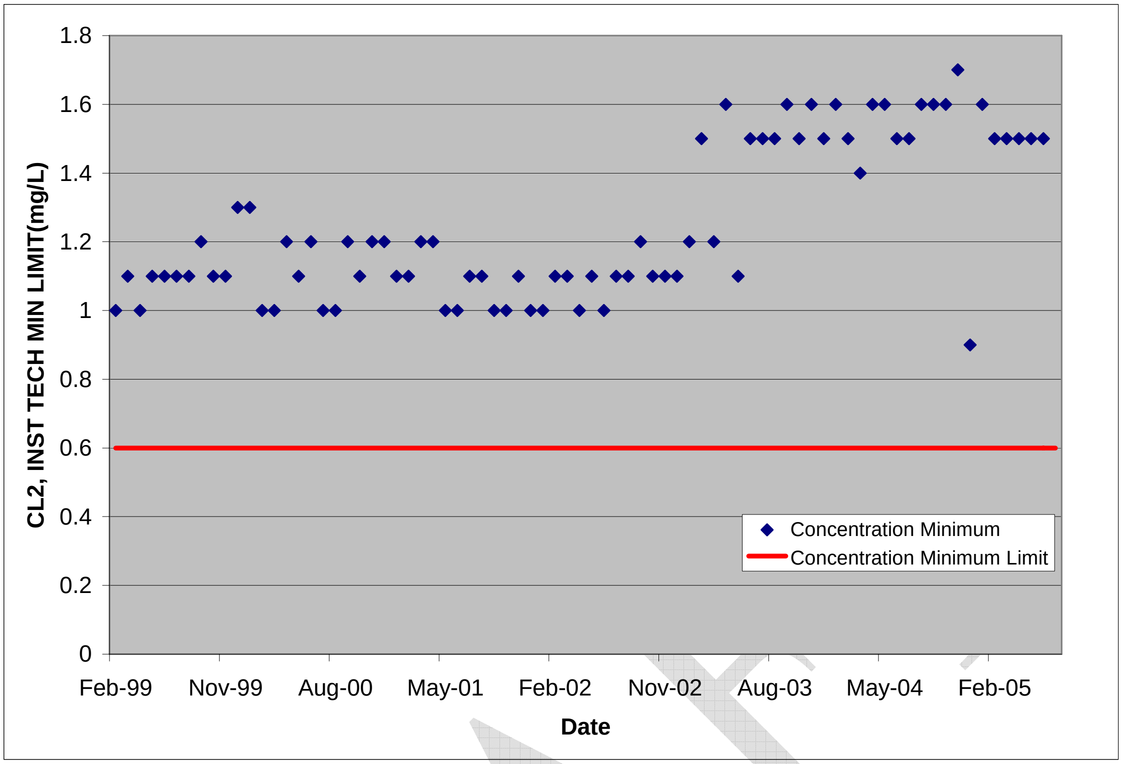


Figure A-55: Moneta Adult Detention Facility Cl_2 Concentrations

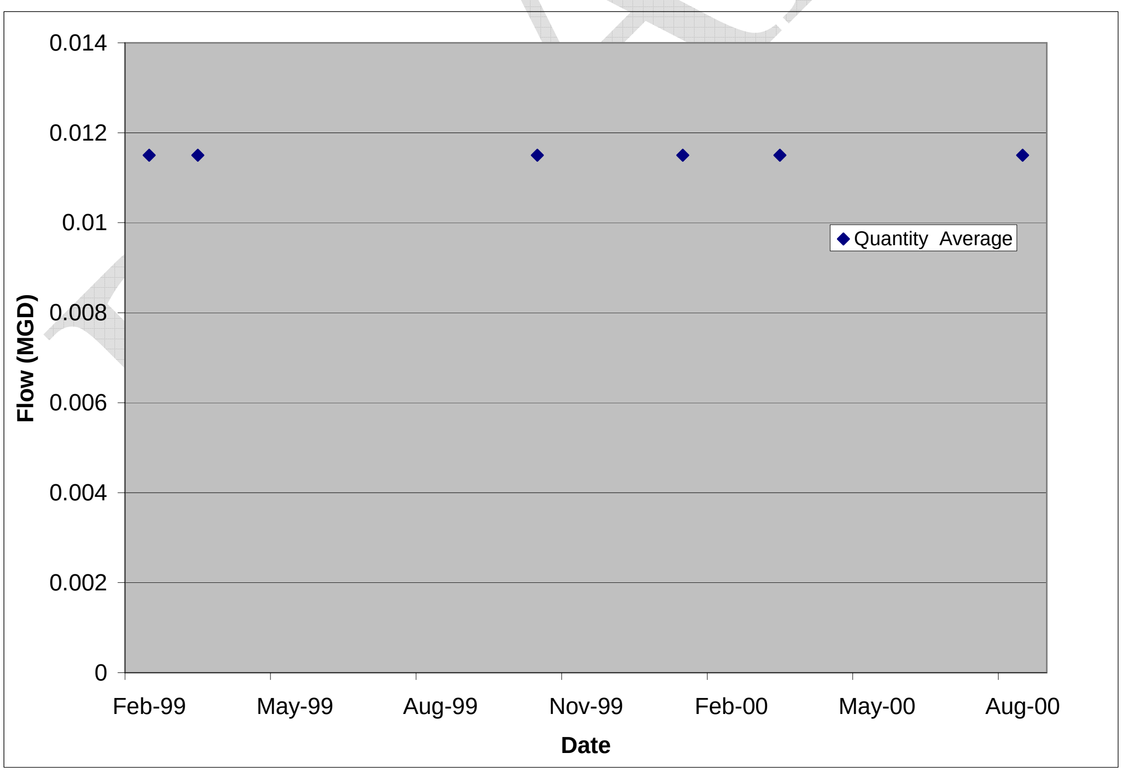


Figure A-56: Motiva Enterprises LLC – Montvale Flow Values

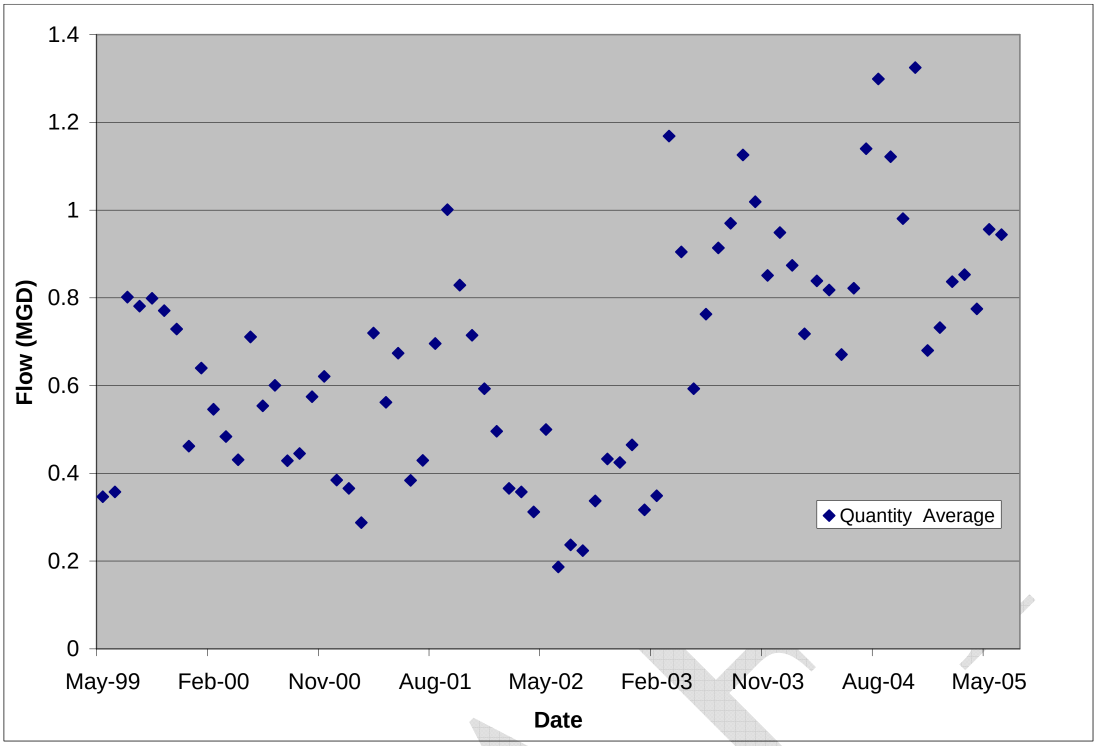


Figure A-57: Old Dominion Electric Coop Clover Outfall 1 Flow Values

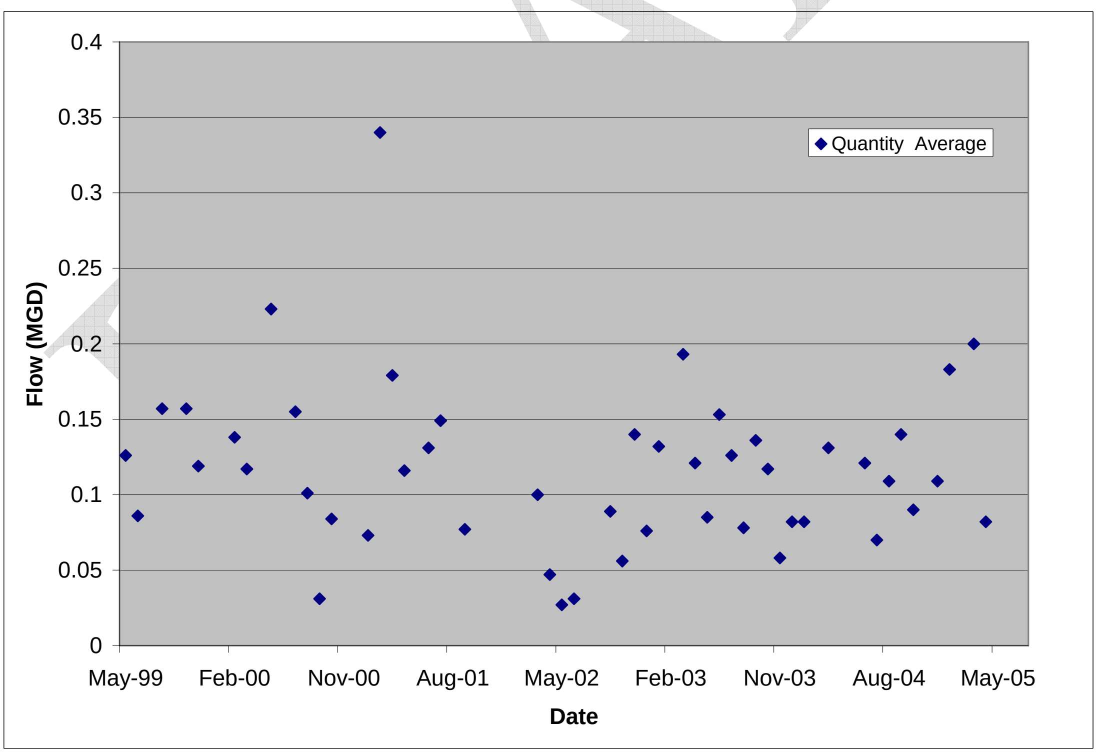


Figure A-58: Old Dominion Electric Coop Clover Outfall 2 Flow Values

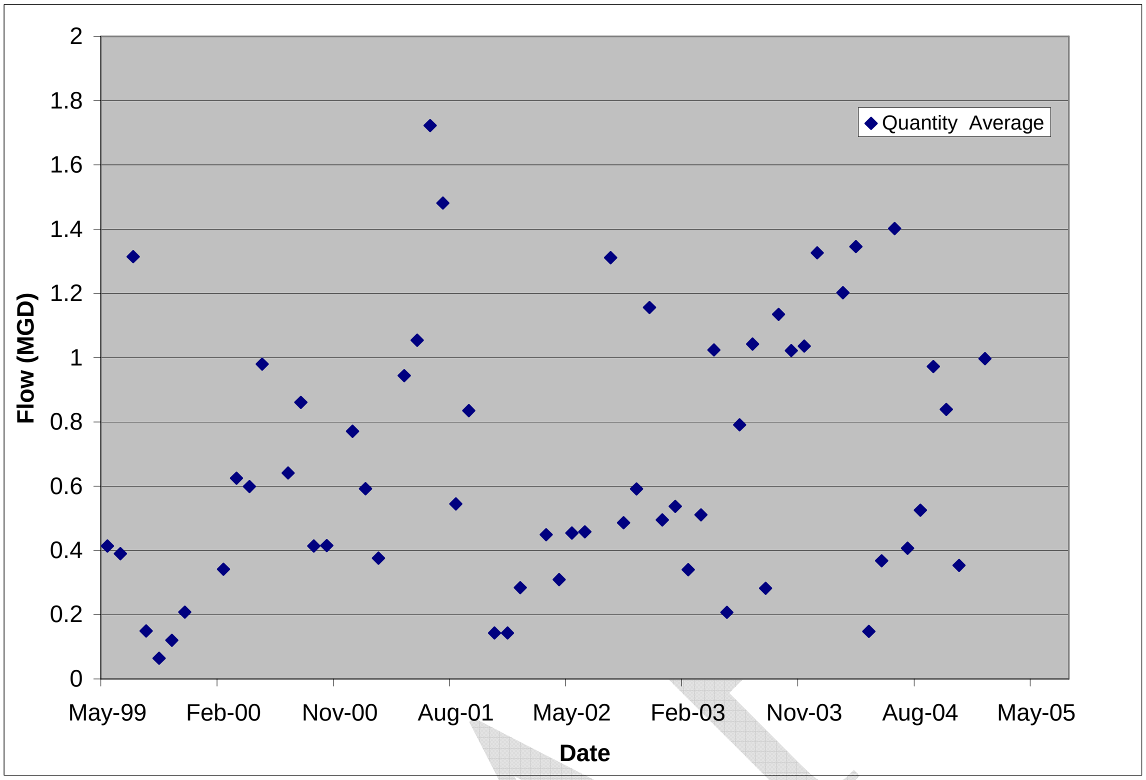


Figure A-59: Old Dominion Electric Coop Clover Outfall 3 Flow Values

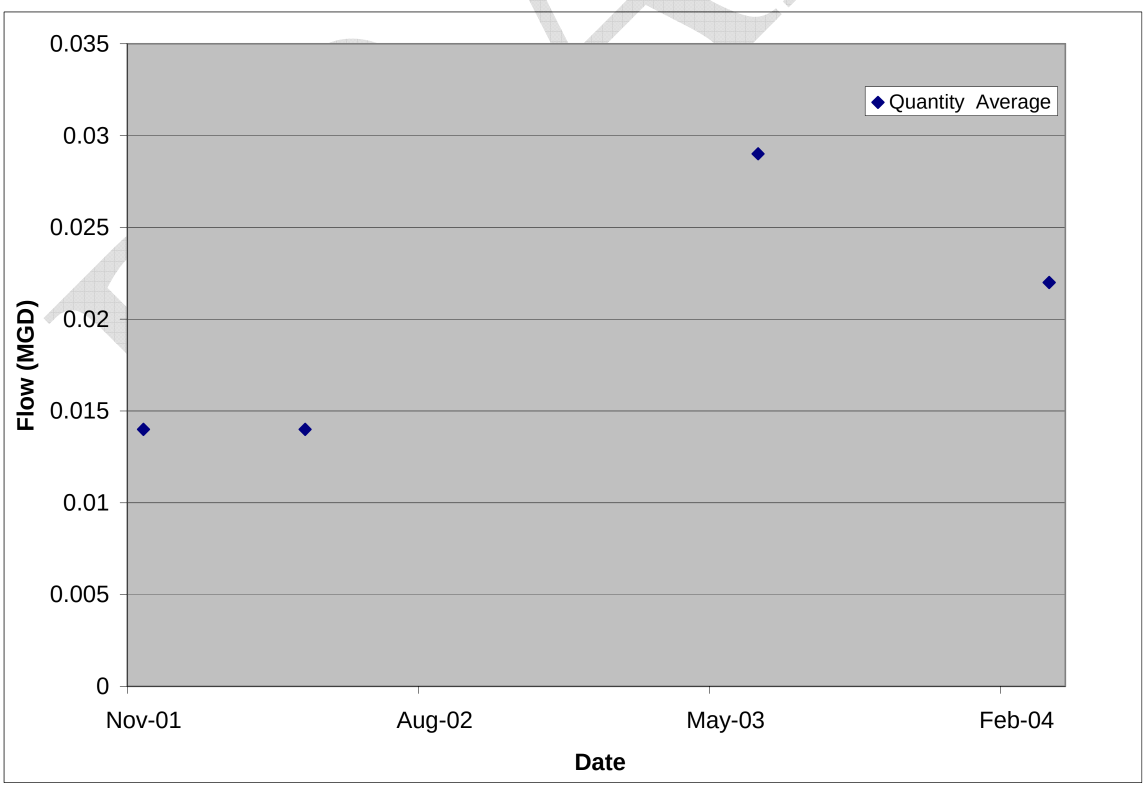


Figure A-60: Old Dominion Electric Coop Clover Outfall 4 Flow Values

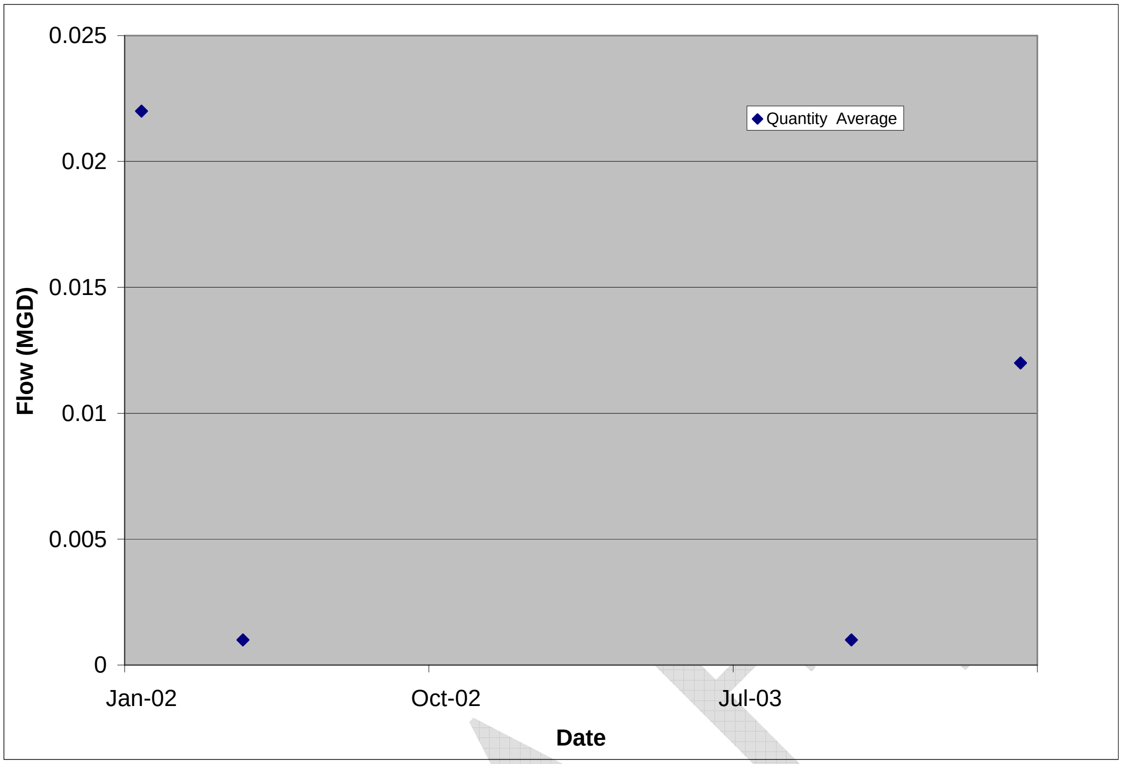


Figure A-61: Old Dominion Electric Coop Clover Outfall 5 Flow Values

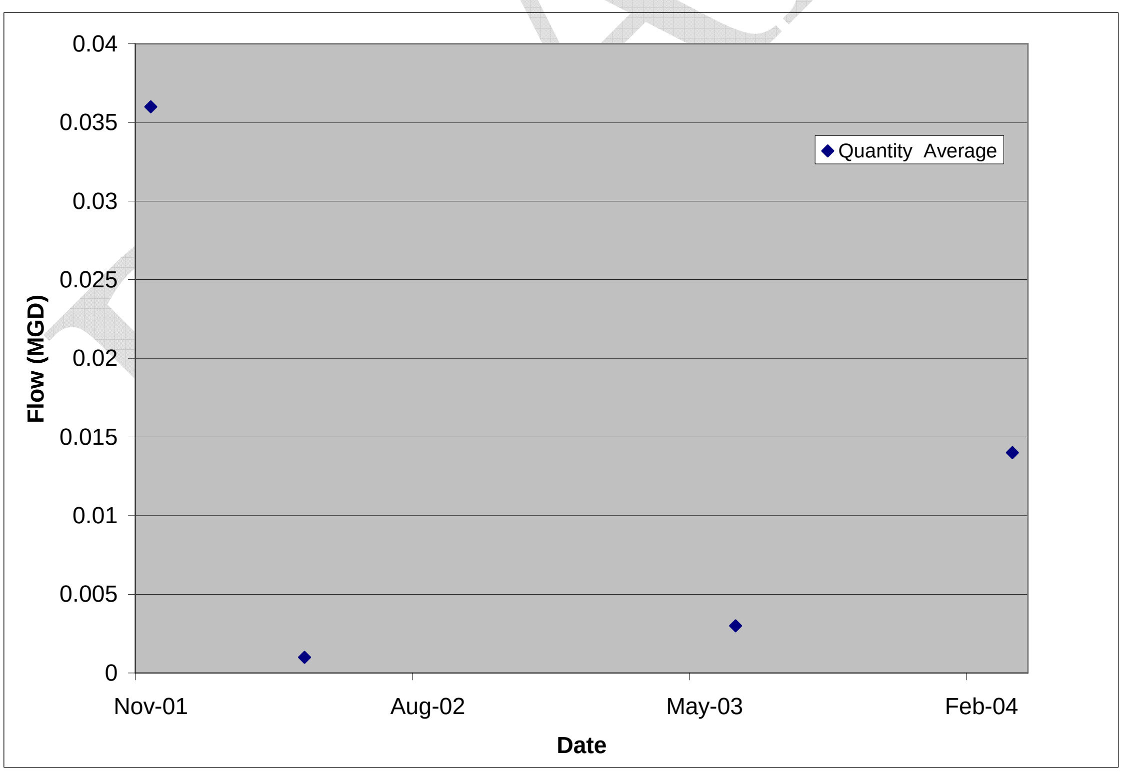


Figure A-62: Old Dominion Electric Coop Clover Outfall 6 Flow Values

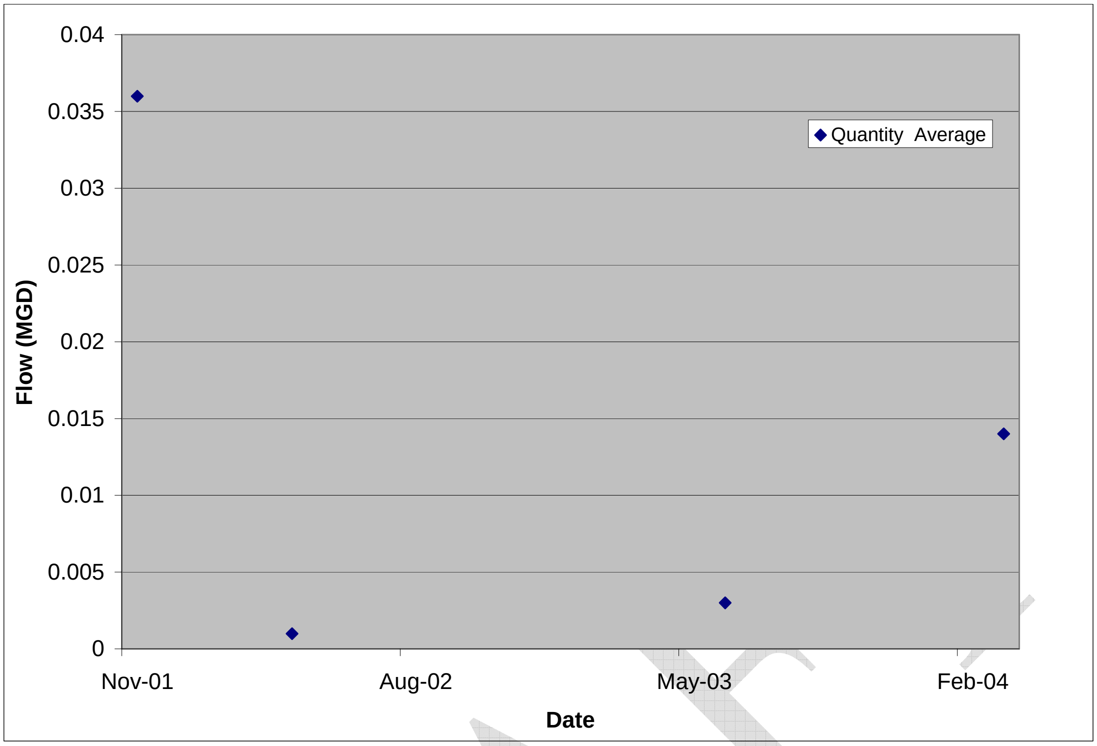


Figure A-63: Old Dominion Electric Coop Clover Outfall 7 Flow Values

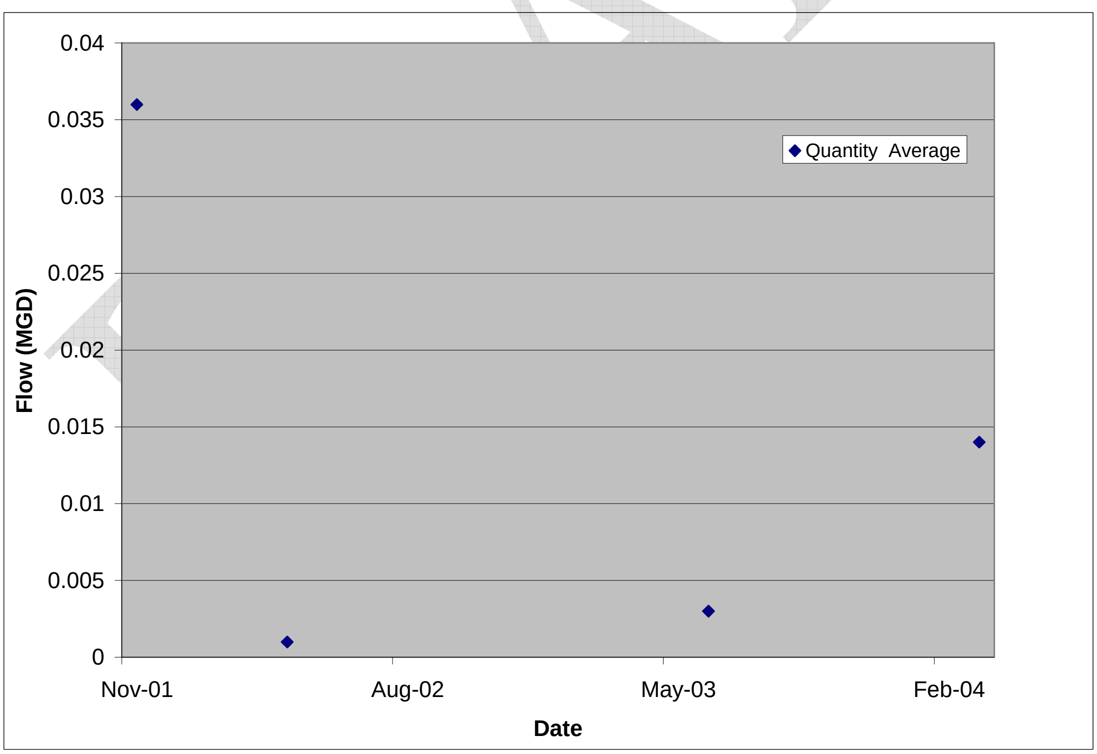


Figure A-64: Old Dominion Electric Coop Clover Outfall 8 Flow Values

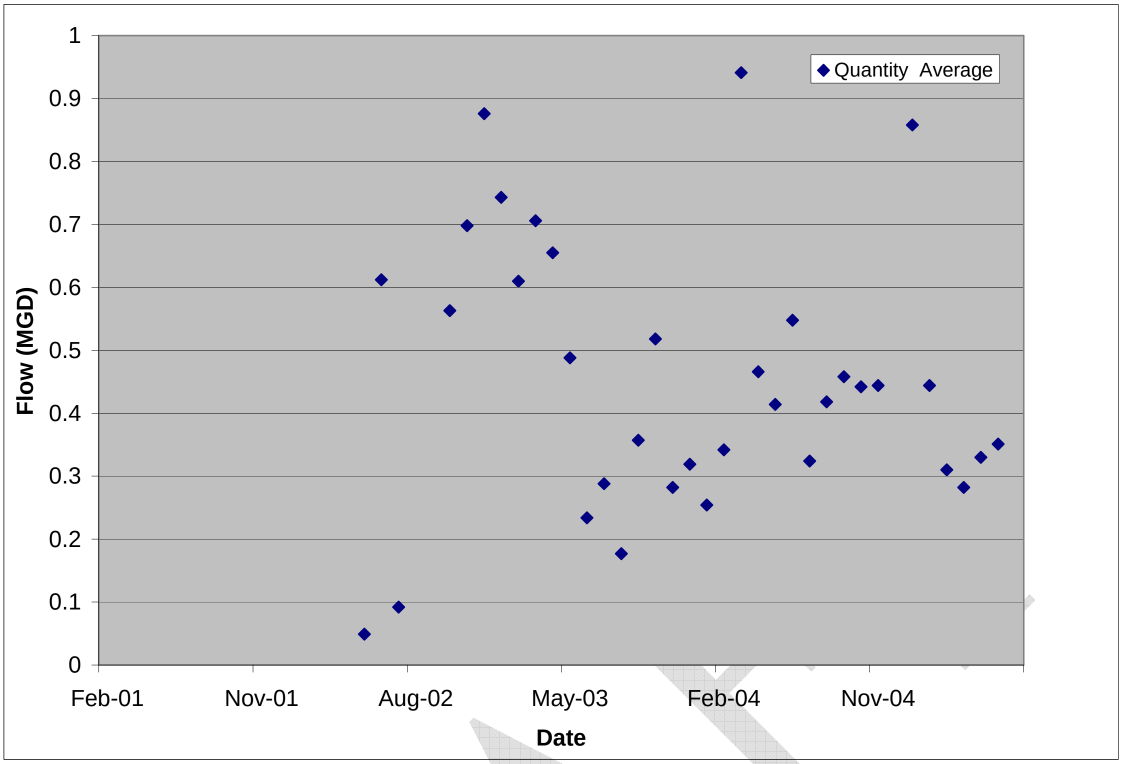


Figure A-65: Old Dominion Electric Coop Clover Outfall 9 Flow Values

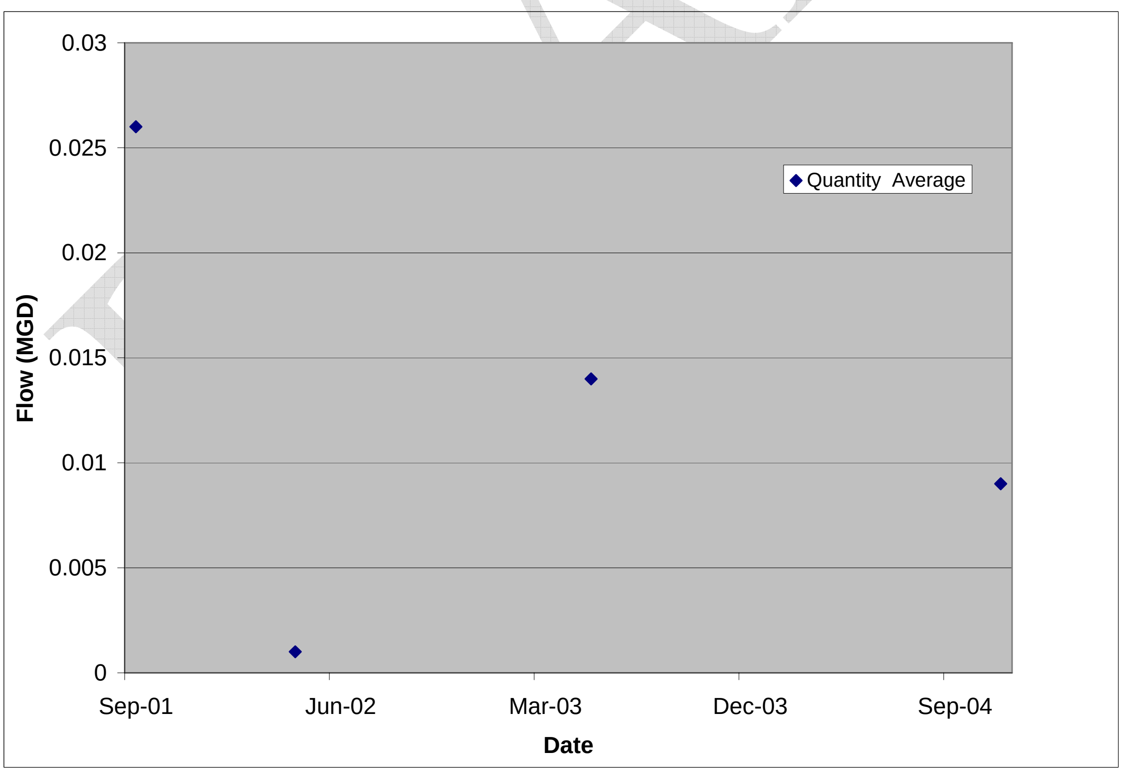


Figure A-66: Old Dominion Electric Coop Clover Outfall 10 Flow Values

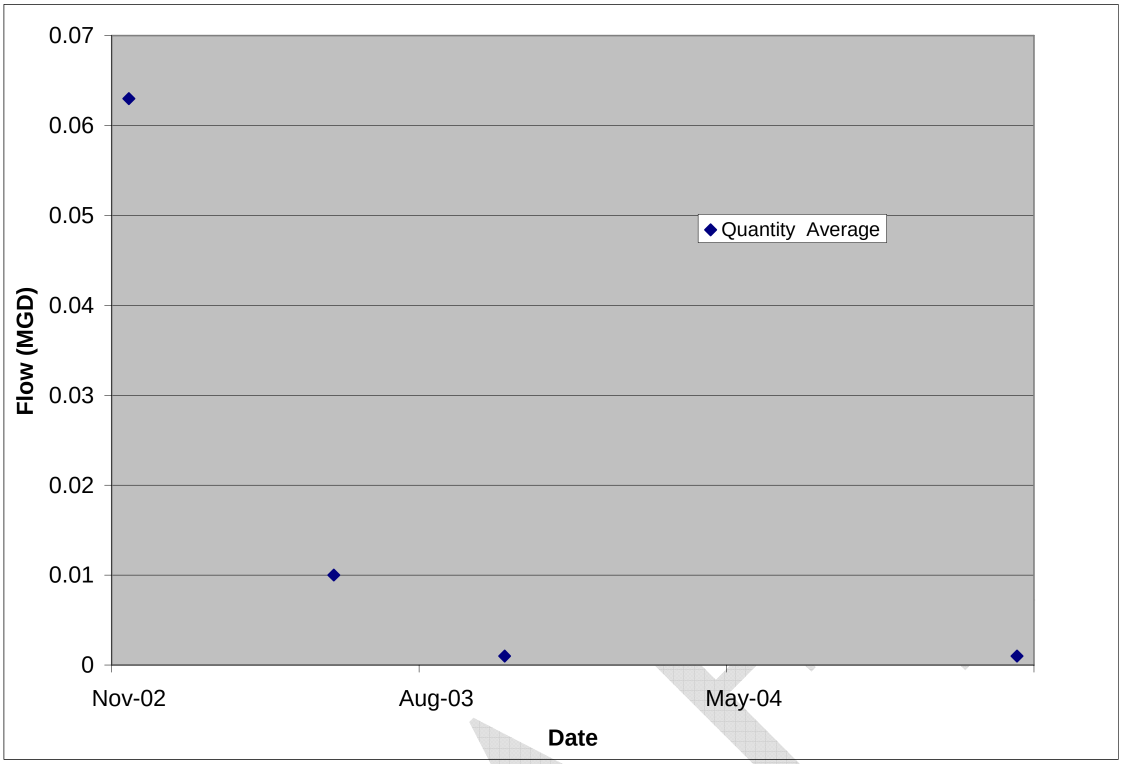


Figure A-67: Old Dominion Electric Coop Clover Outfall 11 Flow Values

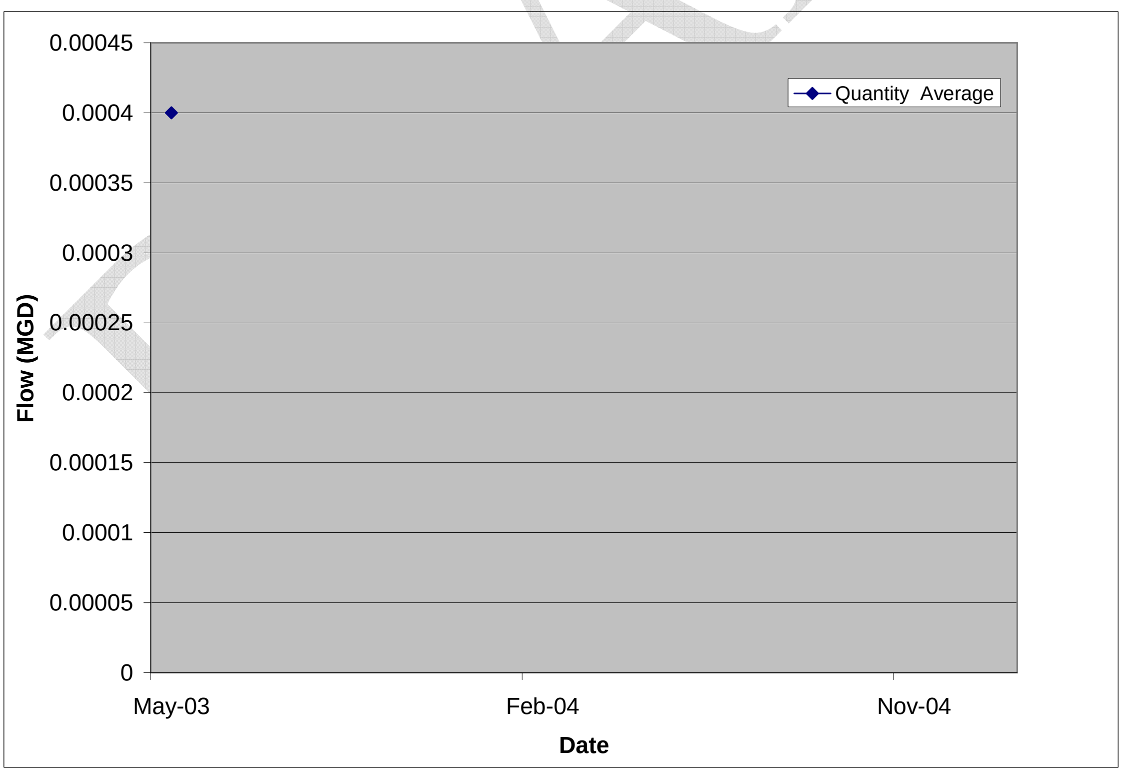


Figure A-68: Old Dominion Electric Coop Clover Outfall 12 Flow Values

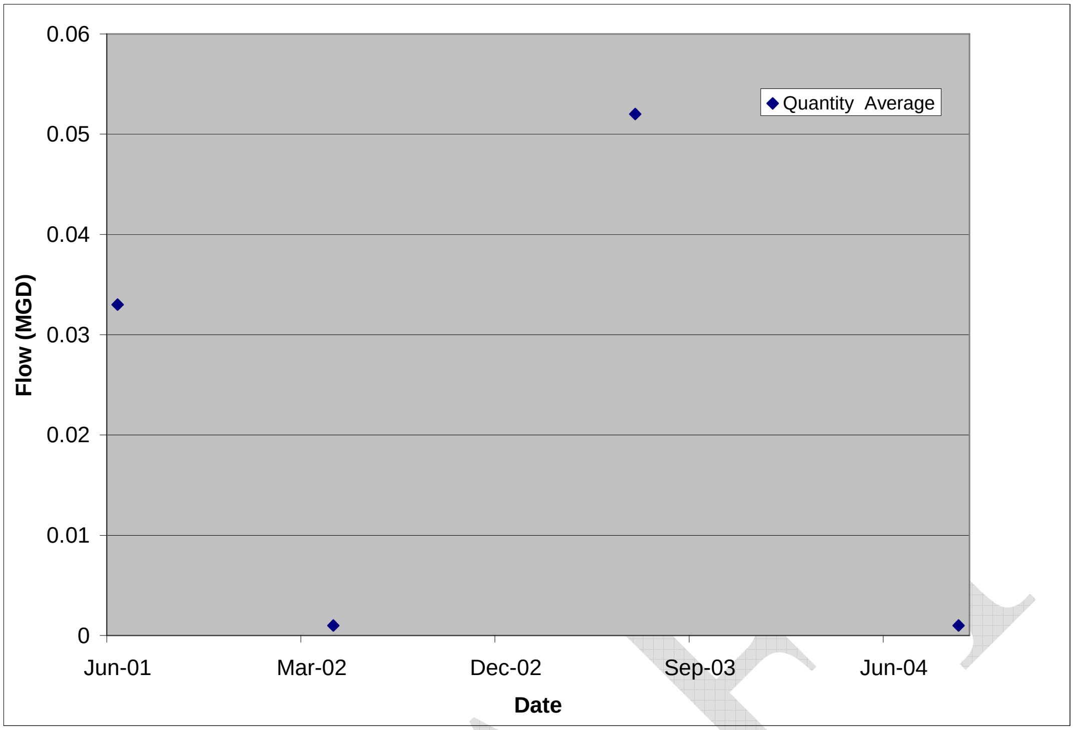


Figure A-69: Old Dominion Electric Coop Clover Outfall 13 Flow Values

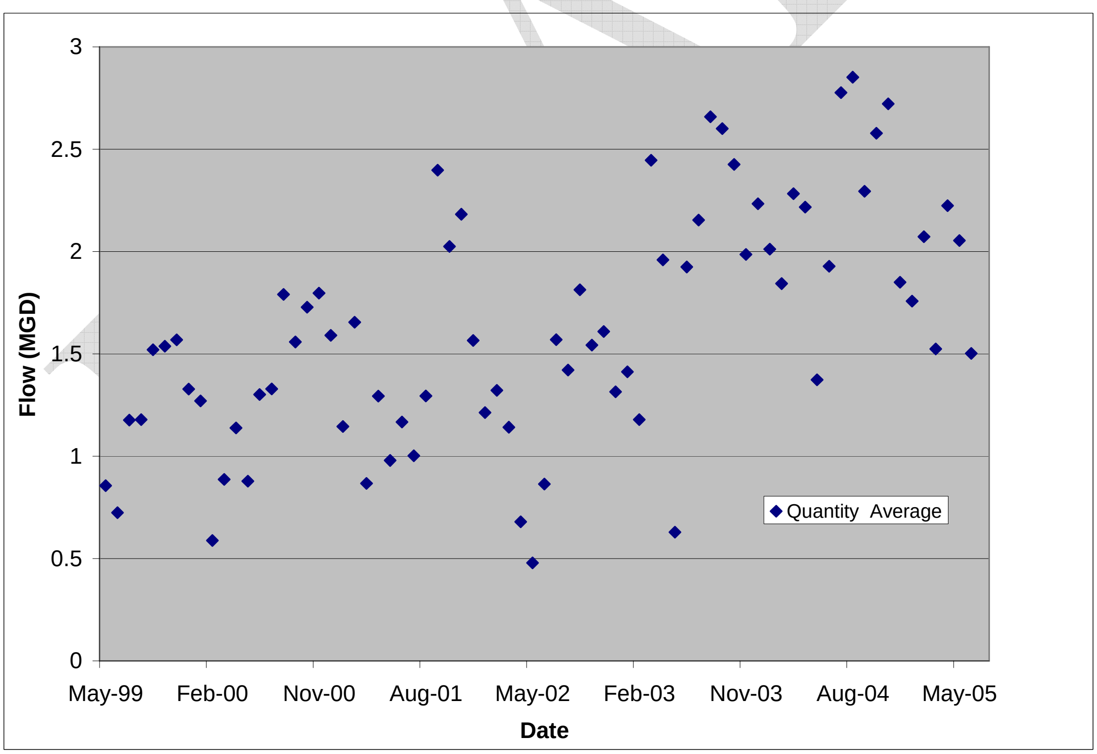


Figure A-70: Old Dominion Electric Coop Clover Outfall 101 Flow Values

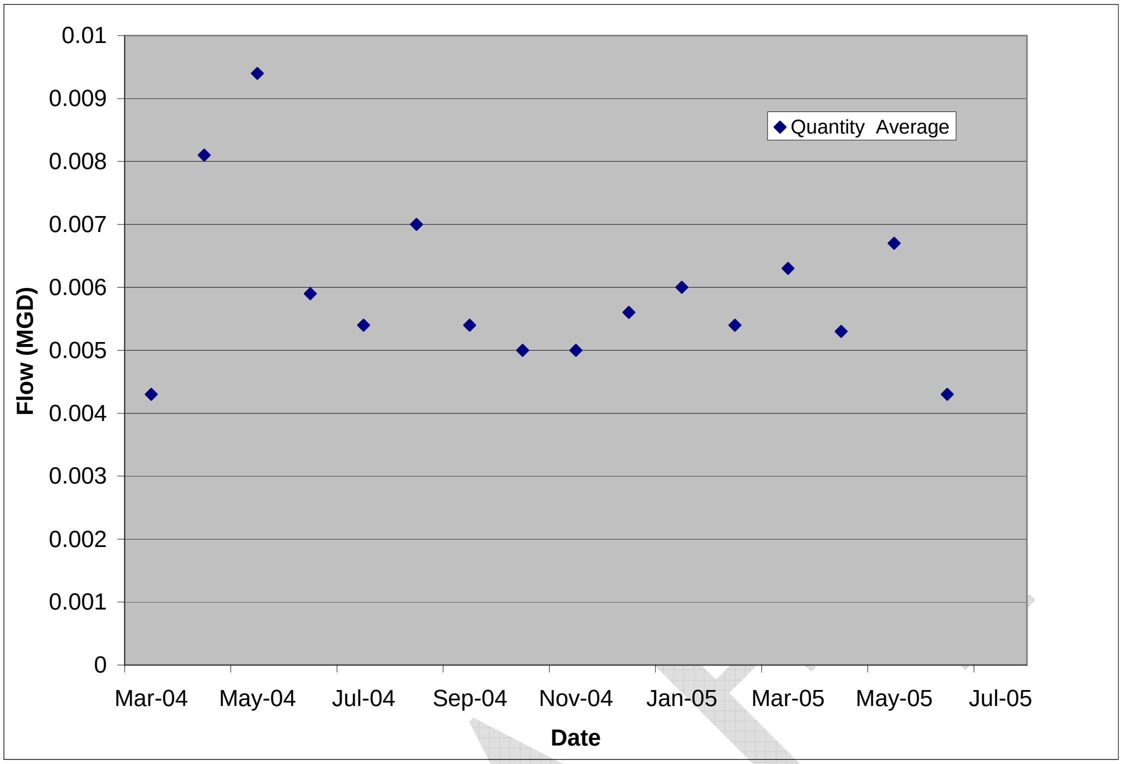


Figure A-71: Old Dominion Electric Coop Clover Outfall 103 Flow Values

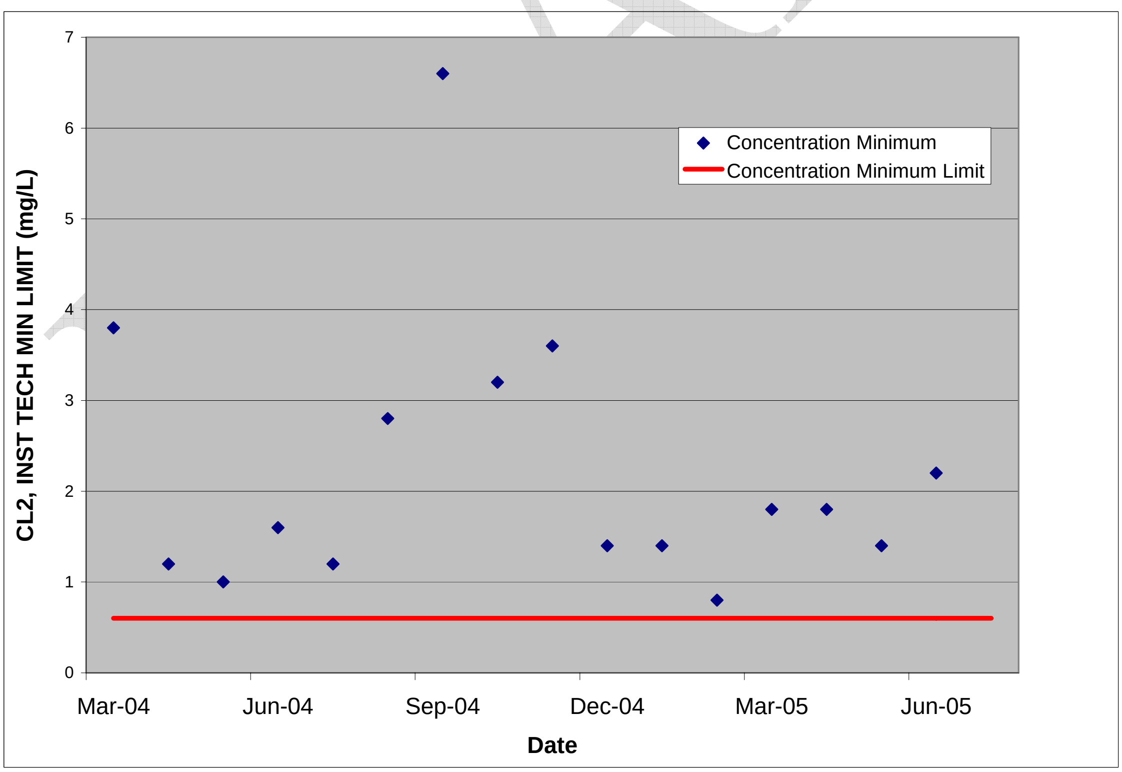


Figure A-72: Old Dominion Electric Coop Clover Outfall 103 Cl_2 Concentrations

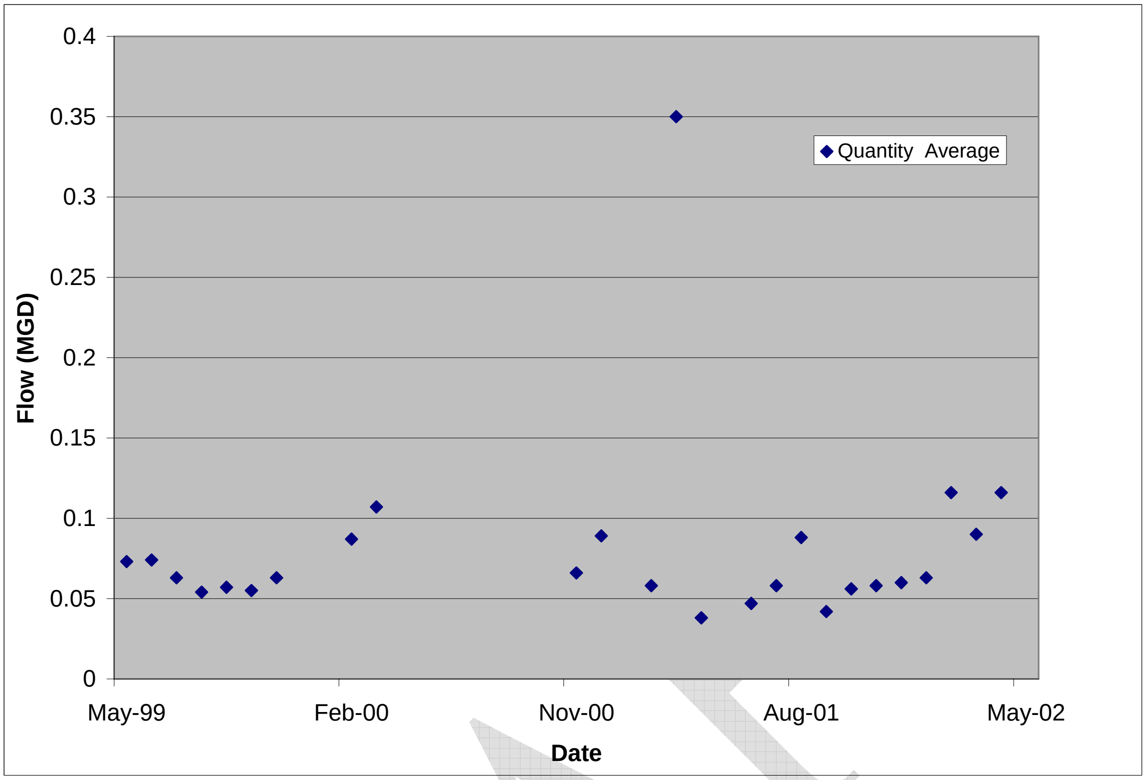


Figure A-73: Old Dominion Electric Coop Clover Outfall 201 Flow Values

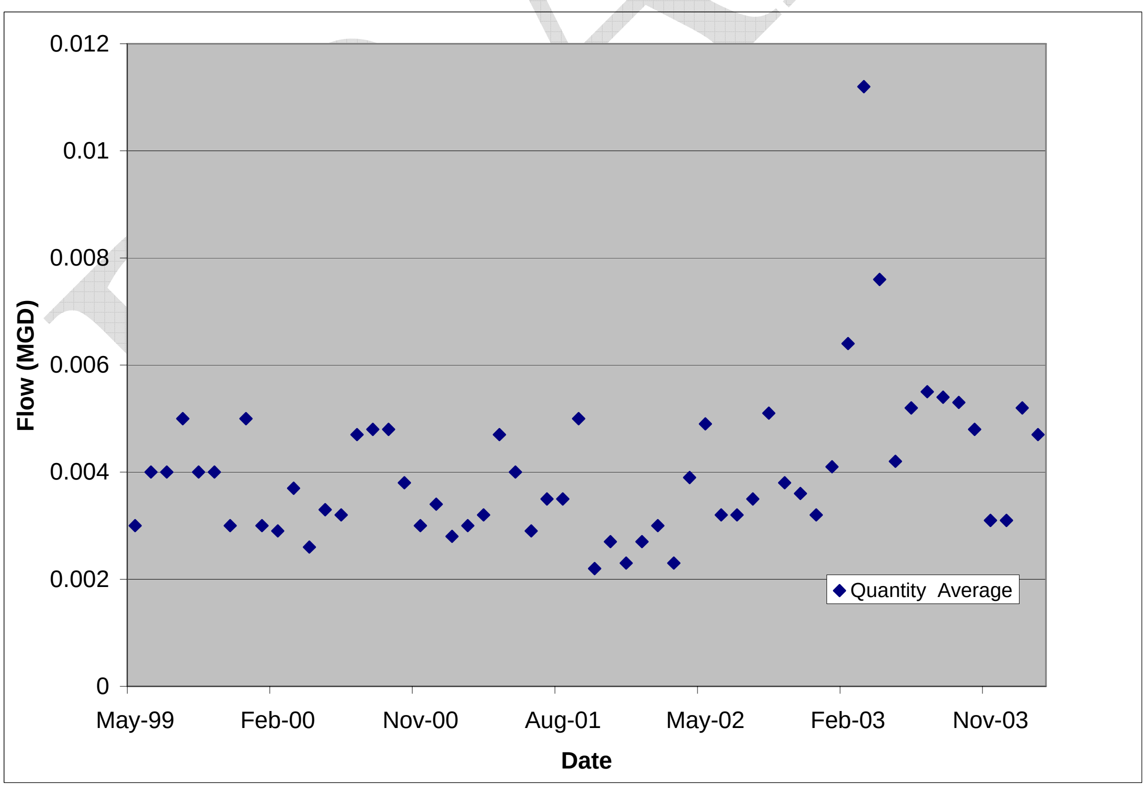


Figure A-74: Old Dominion Electric Coop Clover Outfall 301 Flow Values

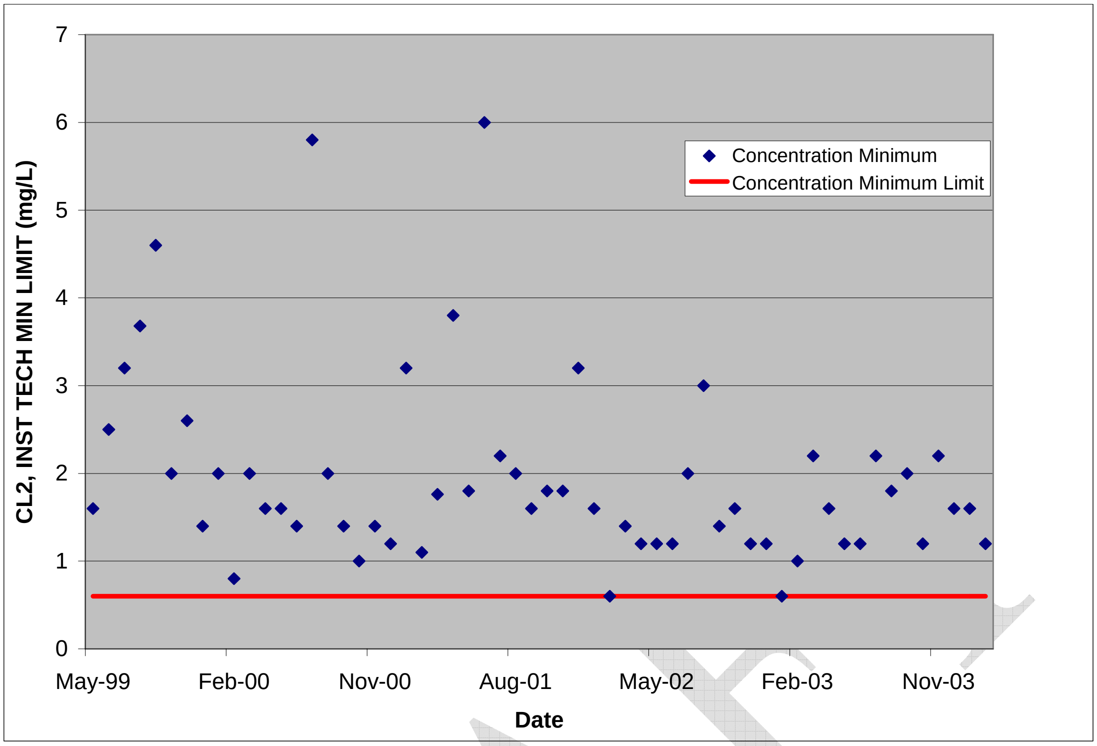


Figure A-75: Old Dominion Electric Coop Clover Outfall 301 Cl_2 Concentrations

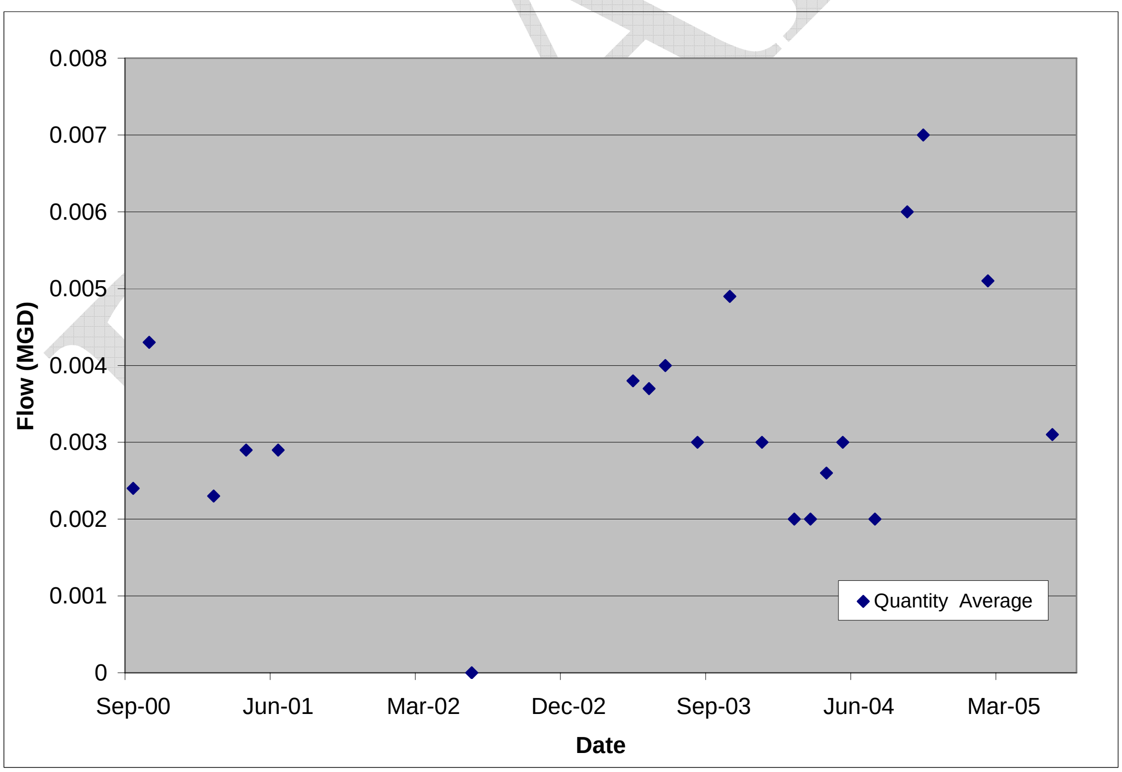


Figure A-76: Trans Montaigne Terminaling Inc – Atlantic Outfall 101 Flow Values

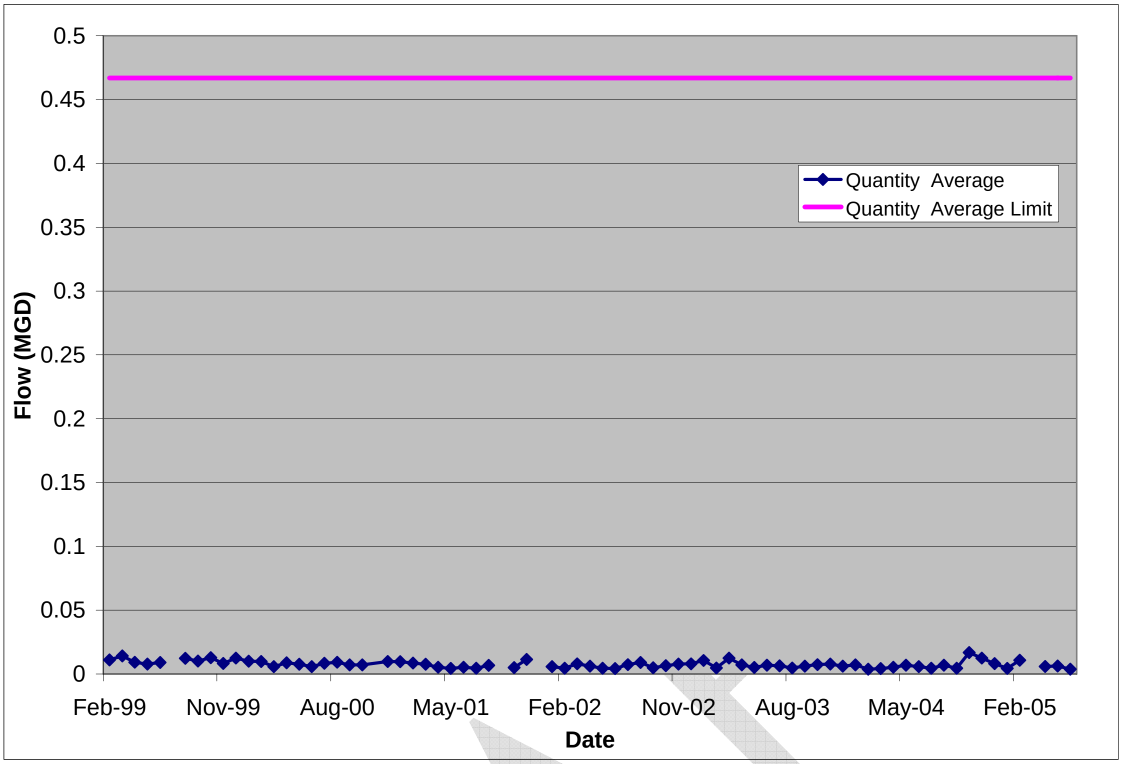


Figure A-77: Trans Montaigne Terminaling Inc – Piedmont Outfall 1 Flow Values

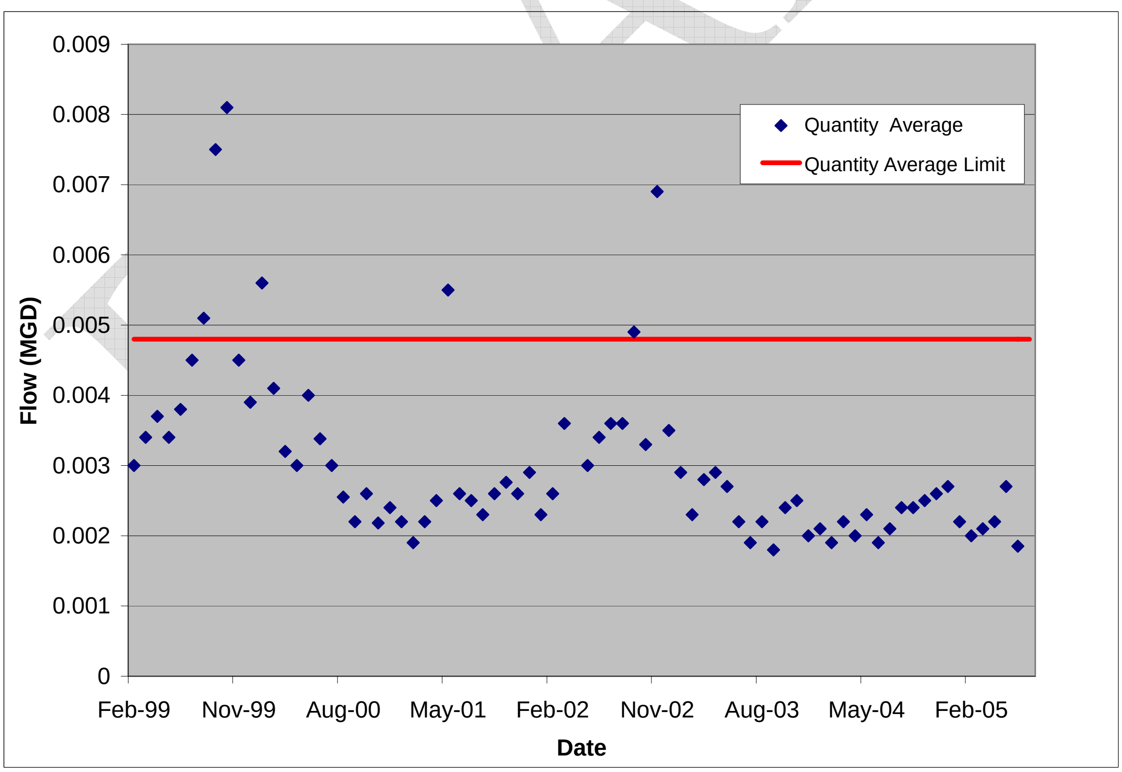


Figure A-78: Woodhaven Nursing Home - Montvale Flow Values

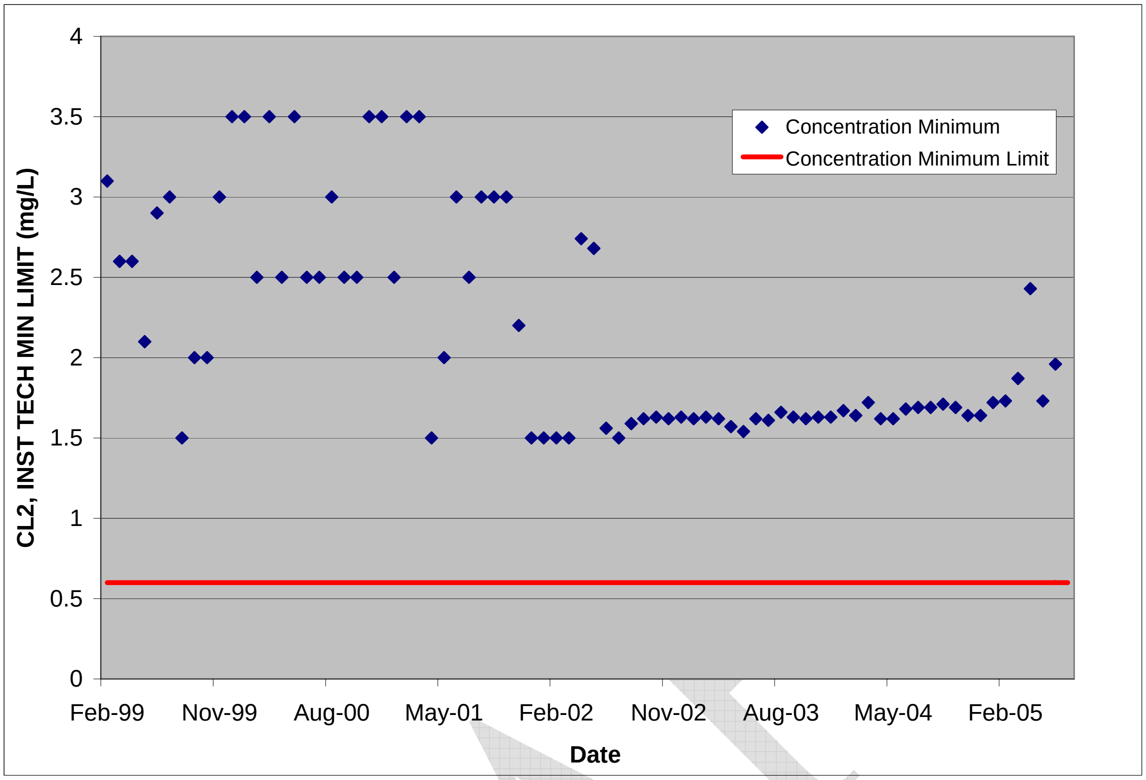
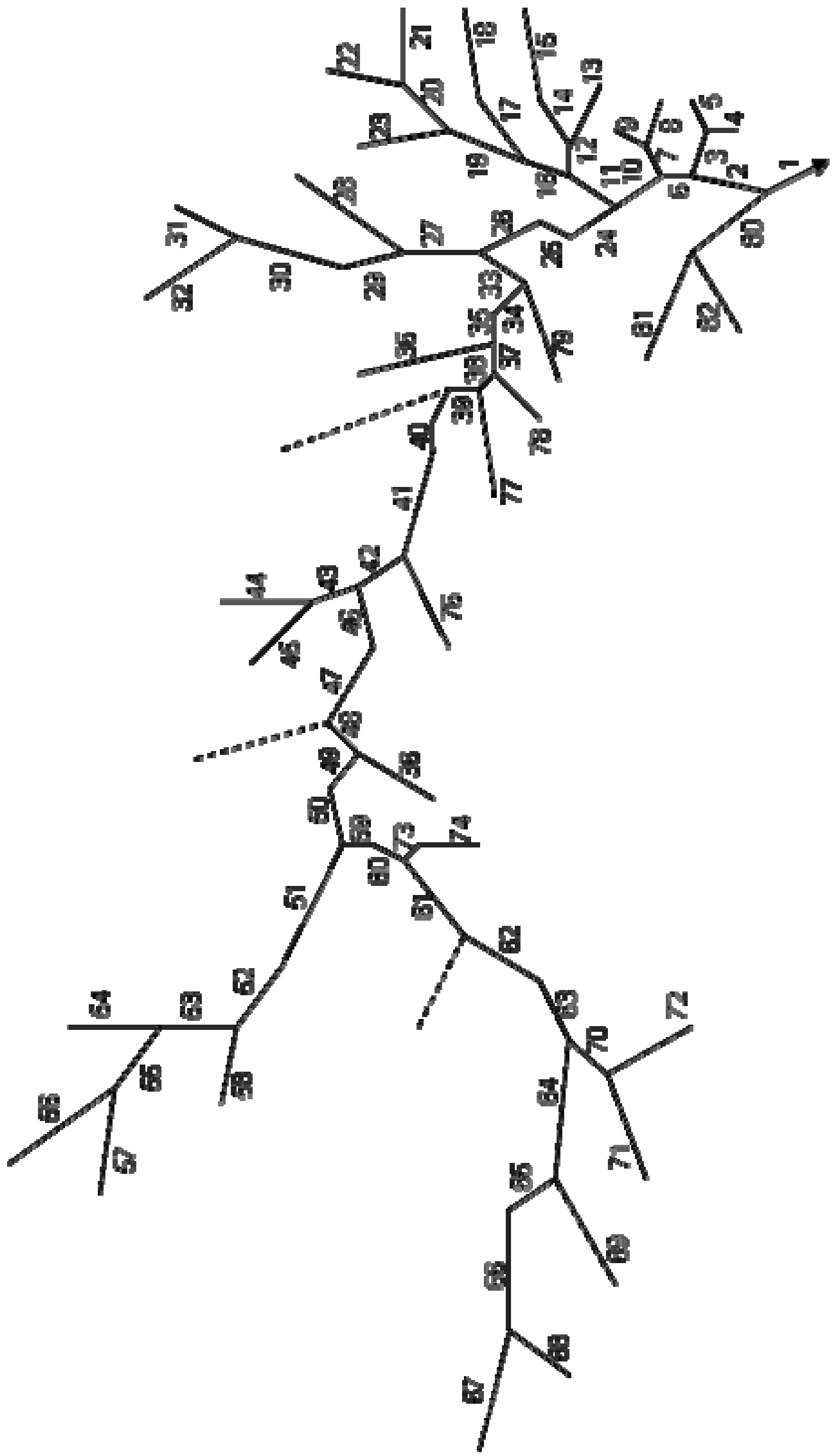


Figure A-79: Woodhaven Nursing Home - Montvale Cl_2 Concentrations

Appendix B

Model Representation of Stream Reach Networks



Model representation of Staunton River Model
Stream Network

Appendix C

Monthly Fecal Coliform Build-up Rates

Table C-1: Staunton River Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	2.64E+07	8.77E+09	7.95E+09	1.68E+10	5.39E+09	1.41E+10
Pasture	4.98E+09	5.33E+09	5.34E+09	5.77E+09	5.34E+09	5.71E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-2: Staunton River Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	5.39E+09	1.41E+10	8.03E+09	1.67E+10	8.66E+09	2.66E+07
Pasture	5.38E+09	5.73E+09	5.49E+09	5.82E+09	5.46E+09	5.06E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-3: Cub Creek Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	2.64E+07	8.77E+09	7.95E+09	1.68E+10	5.39E+09	1.41E+10
Pasture	4.98E+09	5.33E+09	5.34E+09	5.77E+09	5.34E+09	5.71E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-4: Cub Creek Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	5.39E+09	1.41E+10	8.03E+09	1.67E+10	8.66E+09	2.66E+07
Pasture	5.38E+09	5.73E+09	5.49E+09	5.82E+09	5.46E+09	5.06E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-5: Buffalo Creek Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	2.64E+07	8.77E+09	7.95E+09	1.68E+10	5.39E+09	1.41E+10
Pasture	4.98E+09	5.33E+09	5.34E+09	5.77E+09	5.34E+09	5.71E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-6: Buffalo Creek Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	5.39E+09	1.41E+10	8.03E+09	1.67E+10	8.66E+09	2.66E+07
Pasture	5.38E+09	5.73E+09	5.49E+09	5.82E+09	5.46E+09	5.06E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-7: Turnip Creek Monthly Build-up rates cfu/ac/day

Land use	Jan	Feb	Mar	Apr	May	Jun
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	2.64E+07	8.77E+09	7.95E+09	1.68E+10	5.39E+09	1.41E+10
Pasture	4.98E+09	5.33E+09	5.34E+09	5.77E+09	5.34E+09	5.71E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-8: Turnip Creek Monthly Build-up rates cfu/ac/day

Land Use	Jul	Aug	Sep	Oct	Nov	Dec
Forest	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07	2.64E+07
Cropland	5.39E+09	1.41E+10	8.03E+09	1.67E+10	8.66E+09	2.66E+07
Pasture	5.38E+09	5.73E+09	5.49E+09	5.82E+09	5.46E+09	5.06E+09
Low Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10
Commercial/Industrial /Transportation	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08	2.76E+08
High Intensity Residential	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10	2.86E+10

Table C-9 Staunton River Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	1.44E+13	5.16E+13	3.28E+13
2	1.44E+13	5.16E+13	3.28E+13
3	2.23E+13	5.16E+13	3.28E+13
4	3.03E+13	5.16E+13	3.28E+13
5	3.03E+13	5.16E+13	3.28E+13
6	3.82E+13	5.16E+13	3.28E+13
7	3.82E+13	5.16E+13	3.28E+13
8	3.82E+13	5.16E+13	3.28E+13
9	3.03E+13	5.16E+13	3.28E+13
10	2.23E+13	5.16E+13	3.28E+13
11	2.23E+13	5.16E+13	3.28E+13
12	1.44E+13	5.16E+13	3.28E+13

Table C-10 Cub Creek Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	1.02E+12	3.39E+12	4.50E+11
2	1.02E+12	3.39E+12	4.50E+11
3	1.56E+12	3.39E+12	4.50E+11
4	2.10E+12	3.39E+12	4.50E+11
5	2.10E+12	3.39E+12	4.50E+11
6	2.64E+12	3.39E+12	4.50E+11
7	2.64E+12	3.39E+12	4.50E+11
8	2.64E+12	3.39E+12	4.50E+11
9	2.10E+12	3.39E+12	4.50E+11
10	1.56E+12	3.39E+12	4.50E+11
11	1.56E+12	3.39E+12	4.50E+11
12	1.02E+12	3.39E+12	4.50E+11

Table C-11 Buffalo Creek Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	1.49E+10	3.40E+10	0.00E+00
2	1.49E+10	3.40E+10	0.00E+00
3	2.27E+10	3.40E+10	0.00E+00
4	3.06E+10	3.40E+10	0.00E+00
5	3.06E+10	3.40E+10	0.00E+00
6	3.85E+10	3.40E+10	0.00E+00
7	3.85E+10	3.40E+10	0.00E+00
8	3.85E+10	3.40E+10	0.00E+00
9	3.06E+10	3.40E+10	0.00E+00
10	2.27E+10	3.40E+10	0.00E+00
11	2.27E+10	3.40E+10	0.00E+00
12	1.49E+10	3.40E+10	0.00E+00

Table C-12 Turnip Creek Monthly Direct Deposition Rates

Month	Cattle (cfu/month)	Wildlife (cfu/month)	Human (cfu/month)
1	3.40E+11	1.15E+12	2.23E+11
2	3.40E+11	1.15E+12	2.23E+11
3	5.19E+11	1.15E+12	2.23E+11
4	6.99E+11	1.15E+12	2.23E+11
5	6.99E+11	1.15E+12	2.23E+11
6	8.78E+11	1.15E+12	2.23E+11
7	8.78E+11	1.15E+12	2.23E+11
8	8.78E+11	1.15E+12	2.23E+11
9	6.99E+11	1.15E+12	2.23E+11
10	5.19E+11	1.15E+12	2.23E+11
11	5.19E+11	1.15E+12	2.23E+11
12	3.40E+11	1.15E+12	2.23E+11

Appendix D

Monthly Distribution of Fecal Coliform Loading Under Existing and Allocated Conditions

Table D-1 Staunton River Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	High Density Residential
1	1.23E+13	6.85E+12	6.67E+13	2.33E+14	9.08E+11	1.34E+11	2.18E+11
2	1.17E+13	1.47E+13	6.86E+13	2.00E+14	7.73E+11	1.41E+11	2.21E+11
3	1.60E+13	2.17E+13	6.57E+13	2.74E+14	1.08E+12	1.54E+11	3.24E+11
4	1.15E+13	1.53E+13	5.17E+13	1.91E+14	7.36E+11	9.63E+10	2.41E+11
5	5.76E+12	1.25E+13	6.66E+13	1.04E+14	3.93E+11	6.08E+10	1.26E+11
6	1.22E+13	1.34E+13	6.57E+13	2.04E+14	7.86E+11	7.24E+10	2.22E+11
7	9.25E+12	1.30E+13	6.74E+13	1.45E+14	5.53E+11	4.48E+10	1.67E+11
8	2.51E+12	1.34E+13	5.15E+13	5.79E+13	2.29E+11	2.91E+10	5.11E+10
9	1.26E+13	1.84E+13	5.65E+13	1.84E+14	6.97E+11	6.63E+10	2.06E+11
10	3.09E+12	1.39E+13	3.87E+13	4.97E+13	1.97E+11	3.55E+10	5.47E+10
11	5.11E+12	6.52E+12	5.22E+13	1.15E+14	4.51E+11	6.31E+10	1.11E+11
12	5.82E+12	1.14E+11	5.76E+13	1.05E+14	4.20E+11	7.70E+10	1.13E+11

Table D-2 Staunton River Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	High Density Residential
1	1.23E+13	1.82E+12	1.93E+13	2.34E+13	9.08E+11	1.34E+11	2.19E+10
2	1.17E+13	3.62E+12	2.00E+13	2.01E+13	7.73E+11	1.41E+11	2.21E+10
3	1.60E+13	4.79E+12	1.94E+13	2.75E+13	1.08E+12	1.54E+11	3.25E+10
4	1.15E+13	3.69E+12	1.54E+13	1.91E+13	7.36E+11	9.63E+10	2.42E+10
5	5.76E+12	3.98E+12	1.88E+13	1.04E+13	3.93E+11	6.08E+10	1.27E+10
6	1.22E+13	4.20E+12	1.88E+13	2.05E+13	7.86E+11	7.24E+10	2.22E+10
7	9.25E+12	4.11E+12	1.94E+13	1.45E+13	5.53E+11	4.48E+10	1.67E+10
8	2.51E+12	3.66E+12	1.48E+13	5.81E+12	2.29E+11	2.91E+10	5.12E+09
9	1.26E+13	4.01E+12	1.64E+13	1.85E+13	6.97E+11	6.63E+10	2.06E+10
10	3.09E+12	3.19E+12	1.12E+13	4.98E+12	1.97E+11	3.55E+10	5.49E+09
11	5.11E+12	1.69E+12	1.52E+13	1.16E+13	4.51E+11	6.31E+10	1.12E+10
12	5.82E+12	1.12E+11	2.04E+13	3.80E+13	4.20E+11	7.70E+10	4.50E+10

Table D-3 Cub Creek Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	High Density Residential
1	8.05E+11	3.07E+11	4.06E+12	1.02E+13	1.62E+10	1.02E+10	2.42E+10
2	7.61E+11	6.52E+11	4.17E+12	8.32E+12	1.32E+10	1.07E+10	2.53E+10
3	1.32E+12	9.72E+11	4.03E+12	1.32E+13	2.09E+10	1.20E+10	4.28E+10
4	8.47E+11	6.93E+11	3.21E+12	8.06E+12	1.28E+10	7.32E+09	2.82E+10
5	3.05E+11	5.49E+11	3.93E+12	3.63E+12	5.76E+09	4.44E+09	1.13E+10
6	8.73E+11	6.03E+11	4.01E+12	8.90E+12	1.40E+10	5.46E+09	2.67E+10
7	6.12E+11	5.74E+11	4.00E+12	5.72E+12	9.01E+09	3.40E+09	1.63E+10
8	1.79E+11	6.31E+11	3.38E+12	2.75E+12	4.34E+09	2.26E+09	5.53E+09
9	8.25E+11	8.43E+11	3.51E+12	7.20E+12	1.14E+10	4.95E+09	2.25E+10
10	1.78E+11	6.43E+11	2.47E+12	2.25E+12	3.57E+09	2.66E+09	5.62E+09
11	3.51E+11	2.98E+11	3.27E+12	5.09E+12	8.06E+09	4.76E+09	1.29E+10
12	4.73E+11	4.89E+09	3.49E+12	5.15E+12	8.18E+09	5.81E+09	1.47E+10

Table D-4 Cub Creek Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland	High Density Residential
1	8.05E+11	2.14E+10	2.80E+11	5.12E+11	1.62E+10	1.02E+10	1.22E+09
2	7.61E+11	3.80E+10	2.94E+11	4.18E+11	1.32E+10	1.07E+10	1.27E+09
3	1.32E+12	5.12E+10	3.09E+11	6.64E+11	2.09E+10	1.20E+10	2.15E+09
4	8.47E+11	3.81E+10	2.37E+11	4.05E+11	1.28E+10	7.32E+09	1.42E+09
5	3.05E+11	3.89E+10	2.59E+11	1.82E+11	5.76E+09	4.44E+09	5.70E+08
6	8.73E+11	4.34E+10	2.75E+11	4.47E+11	1.40E+10	5.46E+09	1.34E+09
7	6.12E+11	4.03E+10	2.61E+11	2.87E+11	9.01E+09	3.40E+09	8.18E+08
8	1.79E+11	3.96E+10	2.27E+11	1.38E+11	4.34E+09	2.26E+09	2.78E+08
9	8.25E+11	4.18E+10	2.52E+11	3.62E+11	1.14E+10	4.95E+09	1.13E+09
10	1.78E+11	3.21E+10	1.73E+11	1.13E+11	3.57E+09	2.66E+09	2.83E+08
11	3.51E+11	1.81E+10	2.26E+11	2.56E+11	8.06E+09	4.76E+09	6.46E+08
12	4.73E+11	4.79E+09	5.21E+11	2.00E+12	8.18E+09	5.81E+09	6.58E+09

Table D-5 Buffalo Creek Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Cropland	Pasture	Forest	High Density Residential
1	8.12E+09	1.12E+10	7.02E+10	8.12E+09	5.69E+07
2	7.68E+09	2.38E+10	7.21E+10	7.68E+09	5.95E+07
3	1.34E+10	3.55E+10	6.97E+10	1.34E+10	6.68E+07
4	8.55E+09	2.53E+10	5.55E+10	8.55E+09	4.09E+07
5	3.08E+09	2.01E+10	6.80E+10	3.08E+09	2.48E+07
6	8.81E+09	2.20E+10	6.94E+10	8.81E+09	3.05E+07
7	6.17E+09	2.09E+10	6.92E+10	6.17E+09	1.90E+07
8	1.81E+09	2.30E+10	5.84E+10	1.81E+09	1.26E+07
9	8.32E+09	3.08E+10	6.07E+10	8.32E+09	2.77E+07
10	1.79E+09	2.35E+10	4.27E+10	1.79E+09	1.48E+07
11	3.54E+09	1.09E+10	5.66E+10	3.54E+09	2.66E+07
12	4.77E+09	1.80E+08	6.03E+10	4.77E+09	3.25E+07

Table D-6 Buffalo Creek Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Forest	High Density Residential
1	8.12E+09	4.56E+08	2.80E+09	8.12E+09	5.69E+07
2	7.68E+09	7.05E+08	2.94E+09	7.68E+09	5.95E+07
3	1.34E+10	9.24E+08	3.11E+09	1.34E+10	6.68E+07
4	8.55E+09	6.83E+08	2.29E+09	8.55E+09	4.09E+07
5	3.08E+09	6.51E+08	2.29E+09	3.08E+09	2.48E+07
6	8.81E+09	7.22E+08	2.49E+09	8.81E+09	3.05E+07
7	6.17E+09	6.61E+08	2.27E+09	6.17E+09	1.90E+07
8	1.81E+09	6.13E+08	1.86E+09	1.81E+09	1.26E+07
9	8.32E+09	7.02E+08	2.20E+09	8.32E+09	2.77E+07
10	1.79E+09	5.07E+08	1.46E+09	1.79E+09	1.48E+07
11	3.54E+09	3.40E+08	2.04E+09	3.54E+09	2.66E+07
12	4.77E+09	1.76E+08	7.41E+09	4.77E+09	3.25E+07

Table D-7 Turnip Creek Fecal Coliform Load: Existing Condition (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/ Industrial	Water/Wetland
1	2.60E+11	1.67E+11	1.49E+12	1.61E+12	7.26E+08	4.02E+09
2	2.45E+11	3.55E+11	1.53E+12	1.31E+12	5.95E+08	4.21E+09
3	4.27E+11	5.29E+11	1.48E+12	2.08E+12	9.39E+08	4.72E+09
4	2.73E+11	3.78E+11	1.18E+12	1.27E+12	5.73E+08	2.89E+09
5	9.84E+10	2.99E+11	1.45E+12	5.72E+11	2.59E+08	1.75E+09
6	2.82E+11	3.28E+11	1.47E+12	1.40E+12	6.31E+08	2.15E+09
7	1.97E+11	3.12E+11	1.47E+12	9.01E+11	4.05E+08	1.34E+09
8	5.79E+10	3.44E+11	1.24E+12	4.33E+11	1.95E+08	8.93E+08
9	2.66E+11	4.59E+11	1.29E+12	1.13E+12	5.10E+08	1.96E+09
10	5.74E+10	3.50E+11	9.08E+11	3.55E+11	1.61E+08	1.05E+09
11	1.13E+11	1.62E+11	1.20E+12	8.02E+11	3.62E+08	1.88E+09
12	1.53E+11	2.66E+09	1.28E+12	8.12E+11	3.68E+08	2.29E+09

Table D-8 Turnip Creek Fecal Coliform Load: Allocation Run (counts/ month)

Month	Forest	Cropland	Pasture	Low Density Residential	Commercial/Industrial	Water/Wetland
1	2.60E+11	2.25E+10	1.85E+11	1.61E+11	7.26E+08	4.02E+09
2	2.45E+11	4.26E+10	1.92E+11	1.31E+11	5.95E+08	4.21E+09
3	4.27E+11	5.72E+10	2.17E+11	2.09E+11	9.39E+08	4.72E+09
4	2.73E+11	3.90E+10	1.73E+11	1.27E+11	5.73E+08	2.89E+09
5	9.84E+10	4.23E+10	1.95E+11	5.73E+10	2.59E+08	1.75E+09
6	2.82E+11	4.61E+10	2.09E+11	1.41E+11	6.31E+08	2.15E+09
7	1.97E+11	4.36E+10	1.99E+11	9.03E+10	4.05E+08	1.34E+09
8	5.79E+10	4.64E+10	1.70E+11	4.34E+10	1.95E+08	8.93E+08
9	2.66E+11	4.82E+10	1.77E+11	1.14E+11	5.10E+08	1.96E+09
10	5.74E+10	3.59E+10	1.29E+11	3.56E+10	1.61E+08	1.05E+09
11	1.13E+11	1.94E+10	1.37E+11	8.05E+10	3.62E+08	1.88E+09
12	1.53E+11	2.61E+09	2.53E+11	3.41E+11	3.68E+08	2.29E+09

Appendix E

Sensitivity Analysis

Sensitivity Analysis

The sensitivity analysis of the fecal coliform loadings and the waterbody response provides a better understanding of the watershed conditions that lead to the water quality standard violation and provides insight and direction in developing the TMDL allocation and implementation. Staunton River flows through a rural setting. Potential sources of fecal coliform include non-point (land-based) sources such as runoff from livestock grazing, manure and biosolids land application, residential waste from failed septic systems or straight pipes, and wildlife. Some of these sources are dry weather driven and others are wet weather driven.

The objective of the sensitivity analysis was to assess the impacts of variation of model calibration parameters on the simulation of flow and the violation of the fecal coliform standard in Staunton River. For the January 1995 to December 2004 period, the model was run with 110 percent and 90 percent of calibrated values of the parameters. The scenarios that were analyzed include the following:

- 10 percent increase in LZSN
- 10 percent decrease in LZSN
- 10 percent increase in INFILT
- 10 percent decrease in INFILT
- 10 percent increase in AGWRC
- 10 percent decrease in AGWRC
- 10 percent increase in UZSN
- 10 percent decrease in UZSN
- 10 percent increase in INTFW
- 10 percent decrease in INTFW
- 10 percent increase in IRC
- 10 percent decrease in IRC
- 10 percent increase in LZETP
- 10 percent decrease in LZETP

The modeled flows for different sensitivity runs were compared with observed flows at the gage and the coefficients of determination of the hydrologic sensitivity analysis are presented in Table E-1. Based on these tables it can be seen that the calibration parameters affect the coefficient of determination in the decreasing order of AGWRC, INFILT, INTFW, IRC, UZSN, LZSN and LZETP.

The sensitivity analysis was also performed for two water quality parameters, WSQOP and FSTDEC, by simulating the fecal coliform concentrations for 120 percent and 80 percent of their calibrated values. The rate of violation of the Monthly Geometric Mean Water Quality Standard was determined for each scenario and compared with the rate of violation under the water quality calibration run. The changes in the rate of violation are presented in Table E-2. The results of the sensitivity analysis show that WSQOP has a more pronounced effect on the violation of the water quality standards than FSTDEC.

Table E-1. Sensitivity Analysis: Variation in Coefficient of Determination With Respect to Variation in Parameters for Simulation Period 1995-2004

Parameter	Coefficient of Determination	
	+10% change in parameter	-10% change in parameter
LZSN	0.787	0.783
INFILT	0.793	0.775
AGWRC*	0.770	0.793
UZSN	0.788	0.779
INTFW	0.789	0.778
IRC	0.788	0.779
LZETP	0.784	0.784
Calibrated Parameters: 0.785		

* Used 0.999 instead of ≥ 1.00 because the valid range for the parameter is 0-0.999

Table E-2. Sensitivity Analysis: Change in Violation Rate From 20% Change in Calibration Parameter Values

Segment #	WSQOP		FSTDEC	
	20%	-20%	20%	-20%
Staunton River (Seg No 21)	0.0%	1.4%	0.0%	0.0%
Buffalo Creek (Seg No. 4)	0.0%	0.0%	0.0%	0.0%
Cub Creek (Seg No. 29)	0.0%	2.8%	0.0%	0.0%
Turnip Creek (Seg. No. 36)	0.0%	0.0%	0.0%	0.0%